6-11-2015

Preliminary design and construction planning of a new Santa Clara University student fitness and recreational facility

Justin Matoi
Santa Clara Univeristy

Steven Sakamoto
Santa Clara Univeristy

Alex Sarr
Santa Clara Univeristy

SANTA CLARA UNIVESITY

Department of Civil Engineering

I HEREBY RECOMMEND THAT THE THESIS PREPARED
UNDER MY SUPERVISION BY

Justin Matoi, Steven Sakamoto, Alex Sarr

ENTITLED

Preliminary Design and Construction Planning of a New Santa Clara University Student Fitness and Recreational Facility

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

BACHELOR OF SCIENCE
IN
CIVIL ENGINEERING

Professor Tracy Abbott ______________________ 6/8/15

Thesis Advisor Date

Dr. Hisham Said ______________________ 6/8/15

Thesis Advisor Date

Dr. Mark Aschheim ______________________ 6/8/15

Department Chair Date

Preliminary Design and Construction Planning of a New Santa Clara University Student Fitness and Recreational Facility

By

Justin Matoi, Steven Sakamoto, Alex Sarr

Senior Design Project Report

Submitted to

The Department of Civil Engineering

Of

Santa Clara University

In Partial Fulfillment of the Requirements

For the degree of

Bachelors of Science in Civil Engineering

Santa Clara, California

2015

Contents

List of Tables 2
Table of Figures 2
Identification of the Problem 3
Alternative Analysis and Description of the Proposed Solution 4
Relevant Ethical Considerations 6
Related Non-Technical Issues 7
  Political 7
  Environmental 7
  Economical 8
  Safety 8
  Aesthetics 8
Applicable Detailed Design Criteria and Standards 9
Facility Layout Design 11
  Exterior Design 11
  First Floor Floorplan 11
  Second Floor Floorplan 12
Structural Design 12
  Structural Design Resources 12
  Initial Challenges 13
  Design Parameters 14
Cost Estimate 17
  Estimating Methodology 17
Life Cycle Assessment 19
  Life-Cycle Cost Analysis 19
  Photovoltaic System 20
Proposed Schedule 21
  Critical Path 23
Site Logistics Plan 24
  Material Delivery Path 24
  Site Logistics Plan 24

Crane Locations 25
Facility Comparison 26
Conclusion 27
Works Cited 28
Appendix 29
Appendix 1 – Complete Cost Estimate 29
Appendix 2 – Gantt Chart of Proposed Schedule 31
Appendix 3 – Building Overlay 33
Appendix 4 – Material Delivery Path 34
Appendix 5 – Site Logistics Plan 35
Appendix 6 – Crane Locations and Radiuses 36
Appendix 7 – Crane Radiuses with 45 feet Governing 37
Appendix 8 – Column Location for First Floor 38
Appendix 9 – Column Location for Second Floor 39
Appendix 10 – Second Floor Beam Sizes 40
Appendix 11 – Roofing Beam Sizes 41
Appendix 12 – Steel Joist Sizes 42
Appendix 13 – Gravity Column Member Sizes 43
Appendix 14 – Lateral Bracing Location 44
Appendix 15 - Calculations 45

List of Tables

Table 1: The advantages and disadvantages of the alternative solutions considered 5
Table 2: A summary of the relevant design criteria for each structural component of our design 10
Table 3: Key structural resources used 13
Table 4: Seismic design parameters 15
Table 5: Square footage comparison of Malley Fitness Center and our design 26
Table 6: Cost comparison of Malley Fitness Center and our design 26

Table of Figures

Figure 1: Special Concentric Braced Framing member sizes 16
Figure 2: Baseline Schedule 23

Identification of the Problem

The Pat Malley Fitness and Recreation Center was built in 1999. At approximately 45,000 SF, the building cost was 8.8 million dollars. Malley includes three full length basketball courts, locker rooms, 10,000 ft^2 workout and cardio space, a multi-purpose room and administrative offices ("Santa Clara University" *Campus Recreation*). Although one of the relatively new buildings on campus; Malley fails to provide the necessary space and accommodations of an active and growing student body. When the building was designed and built, the student population/enrollment of the University was "approximately 4,200 undergraduate and 3,600 graduate students" (Santa Clara University Bulletin 1999). Since that time, the university has grown to "5,250 undergraduate students and 3,269 graduate students" (Santa Clara University Bulletin 2014). Further, per the Santa Clara University enrollment plan, the university plans to expand student enrollment by ten percent by 2020, which would bring the total number of undergraduates to around 6,000. This is an increase of almost 50% in number of students, since Malley was originally designed ("Santa Clara University" - Enrollment Plan 2014). Renovations and new construction projects, including two new residence halls and new educational buildings, are planned to help support this enrollment growth. Yet, while these new facilities will satisfy the educational needs, recreational facilities cannot be ignored.

Compared to other similar sized private colleges, the Pat Malley Fitness Center has one of the smallest workout and cardio spaces. For example, Gonzaga University's Kermit Ruldolf Fitness Center offers students a "13,000 SF power floor, 12,000 SF cardio/Hammer Strength floor, a mat area, 2 fitness rooms, 3 racquetball courts, an 18,000 SF field house, 1/11 mile indoor track, men's and women's locker rooms, and a 25yd pool" (Kermit Rudolf Fitness Center 2003). Comparing that to Malley's 10,000 SF workout and cardio space, coupled with the fact that Gonzaga University has an enrollment of 1,000 less students, shows that Santa Clara University needs to upgrade their fitness facility offered to their students. Even more locally, however, Santa Clara's' recreational facilities cannot compete with local universities like Stanford.

Compared to the Arrillaga Outdoor Education and Recreation Center on Stanford University's campus, Malley again falls dramatically short in its offered features. The Arrillaga Center includes 75,000 square feet of indoor recreation-based facilities, roughly 30,000 SF more than is offered in Malley, and a 50 meter outdoor pool. Additional features unique to the Arrillaga Center include a climbing wall, three indoor basketball courts, three exercise studios and a 14,000 SF area for cardio and strength training equipment. Further, Stanford offers a second recreational facility, the Arrillaga Center for Sports and Recreation. This again is a 75,000 SF building, which also provides 11,000 SF area for weight machines and cardio equipment. Similarly, it has three full length basketball courts, climbing wall, squash courts, fencing center and a 3,600 square foot studio used for yoga, Taekwondo, and Judo ("Recreation Leading the Stanford Experience" 2014). Stanford represents a geographical rival and competitive standard for Santa Clara University. As Santa Clara continues to grow in both educational standards and enrollment, the University should not neglect the priority of providing a state of the art fitness center.

Santa Clara University should not be neglecting the impacts that fitness centers have on personal wellness and it should be viewed as a priority and have the same importance as educational buildings. Our proposed redesigned building will be a two storied building that provides increased workout, cardio and basketball space, as well as additional multi-purpose rooms and specified areas for badminton and racquetball. The locker rooms and office space will remain, but will be upgraded to reflect the quality our university promotes.

Alternative Analysis and Description of the Proposed Solution

Our design team considered several alternative solutions before ultimately deciding to construct a new facility at the current location. While each additional option we considered each had their own merit, whether it is low cost or continuing availability of a fitness center, each fell short in one category, a long term solution. Our design team felt that each of the alternative solutions considered was only a temporary fix to the overall problem. Our design tackles all of the issues currently facing our fitness center, whether it is a lack of workout space or limited availability of basketball court. One option considered does allow for the continuing availability of a fitness center as well as presents a long term solution; this option is building a new facility in a new location. However, as anyone familiar with our campus knows, it is already overcrowded and there is limited space available for construction of new facilities. Thus this option would require that the school purchase land off campus, resulting in a higher overall cost.

Additionally, this would push the student housing options further and further away from campus. As a team, however, we understand the drawbacks of our solution, the elimination of an on-campus fitness center for an entire academic school year. This issue could be offset by creating reciprocity agreements with neighboring gyms that would allow students to still have access to a fitness center. However, we believe that our solution will accommodate all of the school planned future growth and serve as a hallmark for our campus for years to come.

Below Table 1 shows a list of the alternative design solutions that our team has considered and their potential advantages and disadvantages.

Table 1: The advantages and disadvantages of the alternative solutions considered

Alternative Solution	**Advantages**	**Disadvantages**
1) Leave Existing Structure without any changes	- No Cost to the School	- Limited space cannot accommodate the university's plans for student body expansion
2) Expansion of the Current Existing Building	- Low Cost - Phased construction would allow students to still have access to facilities	- Limits potential availability of new activity areas - Would require high contingency cost for potentially unknown or unforeseeable conditions - Potential for safety hazards to students with construction being in the middle of campus
3) Relocation of Newly Designed Facility	- High cost - Would allow students to still have access to a gym while construction was going on - Would open space for new buildings or dormitories	- Would require the university to obtain land, which they currently do not own - Would limited the availability of off campus student housing
4) Design a New Facility within the Existing Site Boundaries	- High Cost - Would allow for an updated look with potentially new activity areas, like badminton	- Would prevent students from having access to a gym for an entire academic year - Potential for safety hazards to students with construction being in the middle of campus

The fourth option was chosen because it allowed our design team the opportunity to add new recreational areas, improve the overall look of our University and provide a facility to the University, which can be used as a model for green design for the future.

Relevant Ethical Considerations

The ethical implications of redesigning Pat Malley fitness and Recreation Center can be complex and in an attempt to solve those ethical issues can bring rise to supplementary ethical issues. The major ethical issue, if Malley were completely redesigned from the ground up, is that the students, faculty members and paying alumni would be without a recreational and workout facility for a scheduled fifteen months. This would include an inability to hold daily pick-up basketball and badminton games, the cancellation of all indoor intramural and club activities like volleyball and basketball, and the loss of a space where students can workout daily. While this may not be a conventional ethical issue, it could become a major inconvenience for the student body and would require potential reciprocity with a local gym or alternative ways of providing a recreational facility for students.

Alternative solutions to this problem are complex and often bring up other potential ethical issues. An additional option is the relocation of the recreational and workout facility to a different part of campus. However, this would either require that an existing building be demolished or additional land acquired, which the university does not already own. This option would lead to families be asked to move and a decline in available off campus student housing. Further, if families prefer not to move, it could potentially delay the project or put the entire project out of commission.

Second, building the new fitness center could also cause the need for a potential increase in tuition. With new environmental standards and the cost of materials increasing every year, there is a much higher cost for sustainable construction. This would adversely affect current and future students who do not regularly use the fitness center, as they would be directly paying for a facility that they do not use. However, this could be offset by school fundraising or large sum donations made to the building of the new facility. Naming rights could make fundraising difficult, as any individual or family who donates a significant portion to the project may stipulate that the money is conditional to the building name being named after them.

Finally, during the actual construction of the facility, there are potential environmental implications that could occur. There is a potential for dust control issues in regard to students and surrounding buildings because the facility is located in the middle of campus. Further, there will be an ample amount of noise due to construction activities. These issues could potentially lead to student discomfort or exterior damage to the surrounding buildings. During the preconstruction process, different alternatives will have to be considered including fabric site fencing to reduce the amount of dust escaping onto campus or windowed construction to limit noise pollution.

While there are many more ethical issues that might arise with this project, our group felt that these examples had the most direct impact on the community and thus were the most important issues to analysis further.

Related Non-Technical Issues

Political

Since Santa Clara University is a private institution, there is no government support available or needed. This means that the redesign of Mally Recreational Facility does not need any public support in order to be built. However, political support will be necessary within the University; such as from SCU President and the Board of Trustees. They will need to approve the design and construction of any new facility. If there is any faculty or students within the University whom are greatly affected by the redesign or construction, they could use political techniques such as a petitioning to affect the design and potential opportunity for construction.

Environmental

Environmental impacts over the life cycle of this project are an important aspect that cannot go overlooked. The building will adhere to the California environmental laws to ensure that the environment remains un-impacted. There will be a minimal environmental impact because of the location and protocols being followed during the design and construction. The use of sustainable materials, photovoltaic panels, and maximizing the use of natural light will reduce the long term impacts from the project.

Economical

Santa Clara University is a private institution and thus will have to solicit funding from donors, raise tuition, or sell bonds and repay them over time. Our redesign of Malley Center and Recreational facility will use photovoltaic solar panels that will reduce the operation and maintenance cost of the building. We will also maximize the use of windows in the building, which will allow maximum amount of natural lighting and limit the amount of lights required. Both of these designs, will help lower energy cost, which will save the University money over time.

Safety

This project has potential safety and health risk for people passing by and working on the project. As with any construction project, there comes a risk with the job. To name a few, there is always a possibility of falling debris, puncturing items or equipment hazards to name a few. Almost all of these circumstances can be avoided by simply following OSHA safety protocols. Another issue our project could face is the dust and noise created during the construction process. Since the building is being built where there are already existing dorm rooms and walkways, it could pose as a health risk for the students and staff of the university. Dust barriers and scheduling the majority of the construction during university breaks could minimize the dust and amount of students disturbed. Next, since the building is located in a high traffic area on our campus, certain safety precautions need to be taken to prevent students from improperly accessing the site, where they could cause injury to themselves. This could be done by having security guards or a barb wired fence surrounding the project site. There also has to be proper spacing for equipment so that operators will feel safe hoisting heavy materials or driving large vehicles.

Aesthetics

Looking around Santa Clara University's campus, one will quickly realize that the university has adopted a standard aesthetic look for all of its buildings. This look is hallmarked by the tan stucco exterior finish and the terracotta shingled roofing. It is important that we incorporate these hallmarks into the design of our building so that the building will fit in with its surrounding. However, while it is important to follow these hallmarks, it is equally important that the design team put their own architectural spin on the design of the building. By architecturally improving and altering the hallmarks of Santa Clara University aesthetics, the new fitness and recreation center can become the new model and standard for all universities buildings.

Applicable Detailed Design Criteria and Standards

In order to redesign Pat Malley Fitness Center, there are many design criteria, standards and codes that must be identified and followed. Design and planning is an essential component in every engineering project in order to reduce risk and ensure a safe and complete design. It is our responsibility as engineers to ensure a safe design and meet all design criteria, thus ensuring structurally sound building for the public to use. These components will include a soils report, steel sizing and selection, input information for the RAM Structural program and calculations for concrete foundations. These plans and calculations will dictate our end product.

As with any building, the first information required is a soils report. This would be a detailed report that presents data including the soil site class, soil bearing pressure, R-Value and recommendations for construction. From the Earth Systems soils report obtained from the University for the existing facility, the allowable soil bearing pressure is 2,500 psf for live and dead loads with an increase of one-third for seismic loading. Using this information and the vertical loads from the columns, the spread and continuous footings of the building can be designed.

Another aspect of the redesign would be the design all of the columns, beams and girders. After a general building footprint is created, the main information needed for the design of these components would be the vertical dead and live loads and the lateral seismic or wind loads. The dead and live loads can be found in the CBC (TABLE 1607.1). Using the CBC, a uniform live load of 100 psf would be used for gymnasiums and a dead load would need to be calculated. The calculated dead load would need to account for the weight of construction materials and service equipment. After accounting for the vertical loads, the lateral loads would need to be considered.

Using the information provided to the public by the USGS, site-specific acceleration response spectrum can be used to calculate the lateral seismic forces. Comparing the forces to the wind loads the building would sustain, the governing lateral loads can be found.

Next, the type of lateral frames would be chosen. Special concentric braced frames were selected based on cost efficiency. Using the RAM Structural program, the live, dead, and lateral loads would be inputted and the beams, columns and girders can be designed to meet building standards in the AISC, ACI and CBC. To check the work of the program, the design engineer must complete hand calculations to ensure that the correct sizing was chosen. This would include sizing for some columns and beams and required.

Finally, the footings would be designed, using the soil bearing pressure, soil site class, concrete strength and the loads from the building. Using ACI, the rebar can be sized and place accordingly. Again, RAM Structural will be able to design the size, depth, and the rebar in the concrete but hand checks must be done to ensure accuracy. Table 2 below, shows a summary of the design criteria needed for each structural component of the project.

Table 2: A summary of the relevant design criteria for each structural component of our design

Project Elements	Design Criteria
Foundations	• ACI code for the design of the size, depth, and rebar needed to meet the requirements of the building • Either spread or continuous footings would be used • Soil site class, soil bearing pressure, concrete strength will be obtained from the existing foundation and soil report provided by the school • Ram Structural Program to help design the footings
Beams, Columns, Girders	• Live/Dead loads (CBC) • Special concentric braced framing (AISC) • Truss Joist Catalog for the selection of truss system • Use RAM and hand-clacs
Roofing	• Type of roofing • Verco decking catalog • Use RAM for decking loads

Facility Layout Design

Exterior Design

As mentioned before, our proposed design will be consistent with the standard aesthetic look of the current buildings on campus. Our exterior of the building will incorporate a tan stucco exterior finish and terracotta shingled roofing. Our roof will also accommodate the use of photovoltaic panels if Santa Clara University chooses to incorporate it into the scope of the design. We will also be incorporating glass panels throughout the building to maximize the amount of natural lighting.

The significant aspect of our design is the addition of a second level to maximize the amount of space for the weight room, cardiovascular equipment, basketball courts, badminton courts, and multipurpose rooms. Our proposed design will have a maximum height of 45 feet with 15 feet level to level and 30 feet high for the basketball courts. Our design team also extended the back of the proposed facility by 50 ft. compared to the current Malley center.

First Floor Floorplan

The first floor comprises of an increased area dedicated to the weight room. Our design for our weight room is 21,842 SF compared to the current Malley Center, which is only 7,192 SF. This is approximately three times the amount of area dedicated to the weight room. As a design team, we knew that the current Malley Center weight room often gets crowded and congested and it was critical to expand the weight room since Santa Clara is intending to expand the student population by ten percent by 2020. The proposed space should benefit and accommodate the growing population.

The first floor also includes five multipurpose rooms compared to only one multipurpose room in the current Malley center. These multipurpose rooms can then be used for Intramural sports, club sports such as Volleyball and boxing, and fitness classes. Our design team also expanded the office area for campus faculty and incorporated a training room that can be used for the student population. The first floor plan is shown in Appendix 8.

Second Floor Floorplan

The second floor consists of four basketball courts, three badminton courts, and two cardio areas. Since basketball is of high popularity among the student population, we thought it was necessary to add an additional court compared to the current Malley Center. Currently the basketball courts are always heavily populated with pick-up basketball games, intramural sports, club boxing, volleyball, and badminton players. By having three badminton courts on the second level, it removes some of the population away from the basketball courts and gives badminton players a dedicated place to play.

Our second floor also is dedicated to cardio space. Our design has 9,932 SF of cardio space compared to the 2,582 SF currently in Malley Center. This allows for more cardio equipment and areas for core workouts. The first floor plan is shown in Appendix 9.

Structural Design

The main purpose of this structural design was to provide accurate initial sizes for cost considerations so that the estimating team will be able to put together a reasonable cost analysis for the materials used in the building. Even though this design is a conceptual project, the design team knows that the school has a plan for a new gym in its master plan. The intent is to give the school a baseline for how much a new gym would cost if they were to pursue this route. The design team will consider the most costly structural components in the building which include the beams, girders, columns, decking, foundations, steel joists, braces, and roofing.

The design team decided to use structural steel as the main material used in this building. The primary reason behind this is that given the short construction period of just the summer when students are not on campus, structural steel has the faster construction rate compared to concrete. Also because of the height of our story-to-story level of the basketball courts, structural steel is a much more viable option because of its constructability.

Structural Design Resources

Table 3 lists the resources that the design team used to complete the structural design of this project. RAM was the main program used and helped the design of beams, columns, lateral bracing, truss system, and foundations. AutoCAD was mainly used in the design phase of the project and helped with the floor plan drawings and column placement locations throughout the building. The CBC, ASCE, USGS, and AISC were used for design parameters that were entered into our RAM model. Verco and Truss Joist Catalogs were used for the selection of our metal decking and truss system. Last, the existing building plans and foundation report was used for general dimensioning and soil properties for the design of the foundation accordingly.

Table 3: Key structural resources used

Resource	Reasoning
RAM Structural Systems	Structural analysis tool
AutoCAD	Drafting and spatial programing tool
California Building Code (CBC)	Design loads
ASCE 7-10 (American Society of Civil Engineers)	Additional design loads and seismic parameters
U.S. Geological Survey (USGS)	Seismic parameters
AISC 360/341 Design Manuals	Structural steel/seismic design
Verco/Truss Joist Catalogs	Design of metal decking and Steel Joist
Existing Building Plans and Foundation Report	Seismic/foundation design and dimensions

Initial Challenges

During the design phase of the building the design team faced a few challenges that will be discussed in detail. The first challenge was the placement of the columns. The design team wanted to minimize the amount of columns in the weight lifting area and to have no columns in the basketball court. The reasoning behind this was that the design team wanted to give more room for machines and have a more open space in the weight lifting area making the large room less cluttered. Also having columns in the basketball area, even if it was on the outside boundaries would pose a big safety hazard for students especially since basketball is a very active sport.

To achieve the goal of minimizing the amount of columns in the weight lifting area, larger columns, beams, and girders were used to cover the long span. The design team looked into the clear height that was remaining for the first floor and agreed that there was enough room for these deeper beams and columns in the design. To address the second issue, the design team decided that the use of a truss system was the only viable option. To clear the 108 feet, 12 steel joist were used that were spaced 23 feet apart from each other. Appendix 8 and 9 show the location of the steel columns in both the first and second floor.

Design Parameters

During the structural design of this building, many design parameters were found and imputed into the RAM model in order to complete an accurate structural design analysis. These design parameters include loads, seismic, and soil properties. The loads were found using the California Building Code (CBC), seismic properties from the United State Geological Survey (USGS) and American Society of Civil Engineers (ASCE 7-10), and soil properties from the existing building soil report obtained by the school.

Loads:

Using the CBC table 1607.1 the live and dead loads for the structure were found. The design team used 100 psf for the whole second floor, and 20 psf for both the upper and lower roofing. For the dead loads of both the second floor and roofing the design team took into consideration framing, fireproofing, composite concrete decking, metal roofing, MEP equipment, and weight lifting equipment. Dead loads of 20 psf and 12 psf were found for the first floor and roofing according. Also noted that for the roofing dead load, photovoltaic panels were also incorporated into the calculation if the school were to use this space for PV panels.

***Seismic Properties*:**

For the seismic design the design team used the ASCE and USGS to obtain the parameters for the lateral bracing system. Table 4 shows these design parameters, values, and source associated with them.

Table 4: Seismic design parameters

Design Parameter	Value	Source
R	7.0	ASCE 7-10
Soil Site Class	D	Foundations Report
Ss	1.50g	USGS
S1	0.60g	USGS
TL	12 seconds	USGS
Importance Factor	1.25	ASCE 7-10
Ct	0.20	ASCE 7-10
Seismic Design Category	III	Design Team

It's also noted that the design team decided to use seismic design category of III. The reasoning behind this is that given the large open areas of the basketball courts and multipurpose rooms the design team feel that this building would be a great location of any post disaster relief efforts for the school and surrounding community.

Foundation Properties:

Using the existing foundation and soil report obtained by the school, the design team was able to find soil properties including the soil site class and bearing pressure of the soil. It was found that a soil site class is site class D which corresponds to a stiff soil, soil bearing pressure of 2,500 psf, and allowable bearing capacity of 4.00 ksf were used for the design of the foundations. Also normal weight concrete will be used for the foundations.

Gravity Beams and Columns:

For the design of all the gravity beams and columns RAM structural was used to size all of these members. Using the live loads and dead loads imputed into the program the member sizes were determined. All columns were not spliced because of the generally short total height of 45 feet. The sizes and location of the beams and girders are located in appendix 10 and 11 and columns in appendix 13

Lateral System:

For the seismic system special concentric braced frames were used for the lateral system. The main reasoning behind this is that compared to moment frames, special concentric braced frames were more cost efficient. It used smaller member sizes and detailing and furnishing is also cheaper compared to moment frames. The design team also wanted to place the framing equally throughout the building so that there would be no irregularities and took into consideration the tributary areas of each frame and made sure that not one frame took any extreme amounts of area. The location of the lateral bracing is located in appendix 14.

For the design of these lateral beams, columns, and bracing the AISC 360/310 were used to calculate the sizes. Figure 1 below show the member sizes for the frame that took the most load and the calculation are located in the appendix

It is also noted that other buildings on campus like the Library and Thomas Bannan Engineering Center incorporate special concentric braced frames into their structural and architectural design. So the design team feels that since our braces will be showing in our new design, it will also match a lot of the other buildings on campus and will not pose any issues with the architectural design that the school has in mind.

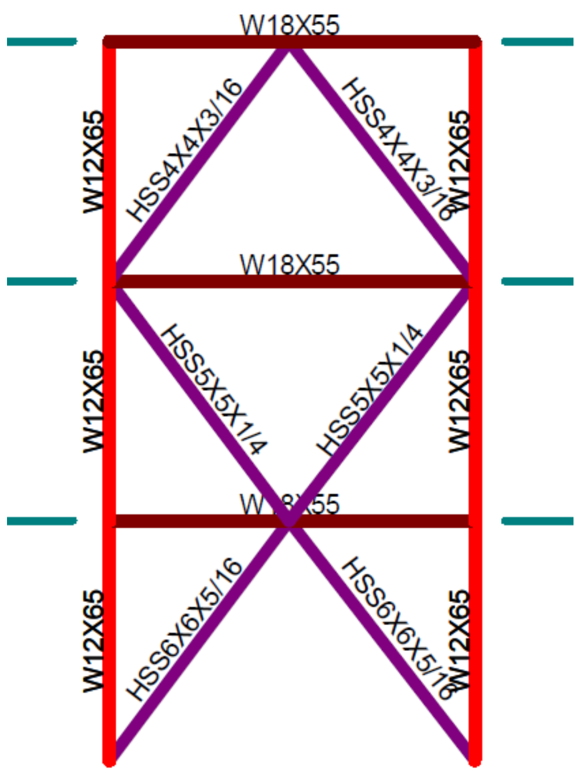


Figure 1: Special Concentric Braced Framing member sizes

Selection of Roofing and Truss System:

Using the Verco and Truss Joist Catalogs the design team was able to choose metal and composite decking for the second and roof level and also choose a steel joist that would be able to sustain the loads. For the second floor a composite concrete deck was selected. It incorporated a Verco PLB™ FORMLOK™ metal deck with 4” of concrete above the flutes. It used a stud length of 5.5” a stud diameter of 0.75” and a concrete strength of 115 pcf. For the roofing a Verco PLN3 metal deck was selected which had a unit weight of 2.5 psf. It was checked that the span length of the metal decking exceeded the span length between beams.

For the truss system, Truss Joist Catalog was used and was found that for the two long spans of 50 feet and 108 feet a steel joist of 28K8 and 60DLH13 was used accordingly. These two steel joists had a capacity of 313 plf and 517 plf which was enough to support the loads of the second floor and roofing. A location of these trusses is located in appendix 12.

Cost Estimate

In this section, the basis of the estimating methodology is analyzed and the lump sum project cost, as well as its breakdown, is presented. This cost encompasses design consultant, preconstruction and the main construction costs. These are accompanied by costs reflecting general conditions, contingencies and a general contractor's overhead and profit. This estimate is based on common construction techniques for mid-rise complex buildings, such as hospitals, offices and university buildings.

Estimating Methodology

The estimate for this proposed project was created using several tools. First, RSMeans books, for both singular construction activities and square footage based activities, was used to gather the construction line items for this project. This included gathering activities such as metal studs, rebar for the elevated slabs and drywall as examples of typical construction activity line items. Included with each of these construction line items was a unit cost, which when multiplied by the quantity of each material allowed for the total cost of that activity to be calculated. Once the construction line items for the project were selected, OnScreen takeoff, in conjunction with our 2-D AutoCad floor plans, was used to perform quantity takeoffs. As mentioned these quantities were then multiplied by the unit cost for each activity to determine the overall cost for a singular construction line item. For our estimate, we broke it down into three separate phases, schematic design, construction documents and construction.

The first phase of the project is the completion of schematic design documents and design development, which has an established fee structure of 10% of the Project Direct cost. For the proposed design, this equates to $1,199,008.32. This fee includes conceptual design phase documents and supporting calculations of the design requirements. This cost also includes the detailed design necessary for the construction of prefabricated elements. These documents will be critical in early assessments of the design and approval to proceed with construction documents given the construction approach we have taken for this project.

The second phase of the project is the preparation of construction documents. These are to be produced by the selected proposer upon the receipt of the notice to proceed from the client. They include the detailed drawings, specifications, site plans, project details, logistic plans, estimates, etc. which are important to proceed ahead with the construction. Actual execution is based on these construction documents. The established fee structure for this phase is 6% of the direct project cost, which equates to $719,404.99.

The third phase of the project is construction. This is the main phase of the project where a majority of the cost for the project is involved. This phase requires management resources, materials, equipment, schedules, etc. It also includes the execution and commissioning of the systems and it’s checking as per the approved standards/drawings. This cost includes the procurement and supply of prefabricated elements. The total direct cost of the project is $18,211,738.

Assumptions and considerations that were made during the cost estimate are:

- The proposed contract value is $18,211,738
- For the analytical tables in the Appendix, the costs that have been estimated are based on the National Average costs. These were then adjusted based on the cost index for San Jose, CA
- General requirements reflect the setup of the construction site, movement of machines to the site and decommissioning, as well as temporary connection to utilities and all project supervision, including a project engineer, superintendent and project manager. This has been estimated to the amount of 10% of direct cost
- The overhead and profit of a general contractor is 15% of the total direct project cost

- Contingency for the project is kept at 7% of the total direct construction cost after considering the risks and local conditions for the project
- General contractors insurance has been taken as 0.64% of the total direct project cost
- Cost for all permits and licenses associated with that project have been estimated as 3% of the project direct cost

Our design team felt that it was important to include the percentage based cost listed above because it would be expected that a general contractor would include these if the project was to be constructed. Further, there were several things omitted from our estimate, like furnishing the workout area. As a team, we realize that our design is currently too large for the current university needs, but as we pointed this is a long term solution, designed to handle all planned future growth, thus we did not want to dictate how the school furnished this new workout area. As a team we imagined a phased furnishing of this area as more and more students attend our university, thus this cost was omitted because it would be difficult to accurately predict how this phased furnishing would occur.

Detailed data and results of the cost estimate can be found in the Appendix.

Life Cycle Assessment

Life-Cycle Assessment is a management tool to evaluate the economic, social and environmental performance of a building over its “effective” life. From our design teams past course experience, we understand the present value of maintenance; operations and utility costs can be as close as the initial project cost. Thus, our design team tried to strive to implement sustainable development into or decision-making process to reduce environmental and long-term cost impacts while meeting our client’s requirements. Few of the enhancements included in the design were chosen for life cycle value each would provide.

Life-Cycle Cost Analysis

Objective:

- Compare life cycle cost of various designs
- Understand the sources of the environmental and economic impacts
- Adopt the most beneficial

A life-cycle cost is a total management tool for long-term ownership cost and framework within a formalized structure of coast planning. Life-cost can examine the trade-offs between low initial costs and long-term cost saving. Below are the approaches that we are going to use once starting from our design phase and during the construction phase.

Approach:

- Material Selection
- Cash Flow Analysis
- Payback Period
- Benefit-Cost Ratio
- Decision

From our design teams' perspective, for a Santa Clara University building, the category with most potential cost impacts is usually the energy system. Having alternative sources of energy are not only more environmentally friendly but also cost effective. Thus it is logical for us to enhance the energy system category. Additionally, our team recognizes Santa Clara University's commitment to sustainability. Thus providing our design team with additional incentive to equip our building with energy efficient systems.

Photovoltaic System

The photovoltaic system is one item we included in our design. It was chosen for its sustainability feature and its eventual positive return on investment. Because the Santa Clara area has about 5 kWh/m^2/day of sunlight, it is a great place to adopt a solar system. Also, having PV system would contribute to achieving LEED certification.

Our team has conducted a cash flow analysis to obtain the amount of money the university could potentially save in utility cost if a PV system was installed. We assumed 3% utilities escalation rate and 5% discount rate, which includes the inflation rate. There are many government incentives for adopting PV systems. We have assumed 60% of installation cost for programs such as GoSolar SF business incentive, federal tax credits and others.

Proposed Schedule

This section describes the general strategy used to develop the project schedule along with key factors that were considered to ensure a smooth execution for its entire duration. These include cost and availability of local labor and materials, construction phasing and the sequence of works. Microsoft Project 2010 was used to further develop the schedule to a level of detail where task durations could be calculated on the basis of the amount of work and resource availability.

The project schedule was prepared based on previous experiences with projects of similar nature with the help of all team members and our faculty advisor. The schedule was designed with the objective to reduce construction crews' idle-time, identifying and accessing the most critical risks. The duration for each Work Package was calculated based in productivity data available and the Quantity Takeoff items estimated. The sequence of work was then adjusted to comply with the major project milestones, site constraints, and the overall construction management strategy.

As a Design Build Project, the Notice to Proceed (NTP) will be given initially for the Design Phase on June 15, 2015. This date signifies the end of the 2015 school year and the start of the Design phase. The Design phase of the project includes preconstruction services such as the structural design, procurement of materials, and the completion of construction documents. The structural design process will take approximately 42 days, which include the schematic design documents and approval. The long lead procurement of materials includes elevators, air handlers, and the design and approval of design development documents. The construction document process include the development of construction documents, quantity-take offs, approval of construction documents, and permitting. This Design phase will take approximately 10 months to complete.

Design of our proposed building was completed in April of 2016, however our design team decided to lag the start of the actual construction date by two months, which signifies the end of the 2016 school year. By lagging the construction, it will allow us to maximize the amount of construction time without the student and faculty population being on campus. This is significant because having construction with students and faculty on campus creates immense safety, liability, and noise issues. By starting construction during the summer it will allow our construction team to proceed with tasks such as demolition of existing and erection of steel to occur with less safety concerns of the surrounding population. Another notable aspect of lagging the construction date is to accommodate the student population by not closing their fitness center in the middle of the school year.

During the calculation of crane locations, our design team was challenged by having construction in a congested area of campus. Our crane locations were initially placed at the end of the buildings; however the crane radius could not cover the middle of the building where our heaviest loads were. Our solution was to construct the building from the middle outwards and move the crane locations accordingly instead of having multiple set locations. This caused our construction schedule to be extended by a month to accommodate the movement of the cranes. By having movement of our cranes it made the erection of steel the only task that could be done during that timeframe instead of different tasks to occur at the same time.

The actual construction will take 304 working days. This includes the demolition of existing facility, footings, final grading, exterior enclosure, interiors, superstructure, and landscaping. The Project Delivery cycle is expected to end with the final Commissioning and Turnover of the facility. A total estimated duration of the project will be 565 days with the following expected date for completion: 8/21/17. Our design team initially had a goal to finish construction by the beginning of the 2017 school year, which is 9/25/17. This thus shows that we will be approximately done with construction one month before our desired goal.

Malley Center Redesign Santa Clara University	**565 days**	**Mon 6/15/15**	**Tue 8/22/17**
Design	**42 days**	**Mon 6/15/15**	**Tue 8/11/15**
Long Lead Procurement	**160 days**	**Wed 8/12/15**	**Tue 3/22/16**
Design Development	40 days	Wed 8/12/15	Tue 10/6/15
Approval of Design Development Documents	3 wks	Wed 10/7/15	Tue 10/27/15
Construction Documents	**120 days**	**Wed 10/28/15**	**Tue 4/12/16**
Mobilize on Site	**5 days**	**Mon 6/13/16**	**Fri 6/17/16**
Start Construction	**304 days**	**Mon 6/13/16**	**Mon 8/21/17**
Demolition of Exhisting Facility	4 wks	Mon 6/13/16	Mon 7/11/16
Footings	**12 days**	**Tue 7/12/16**	**Wed 7/27/16**
Final Gradings	3 days	Fri 7/22/16	Tue 7/26/16
Exterior Enclosure	**127 days**	**Wed 7/27/16**	**Wed 1/25/17**
Interiors	**118 days**	**Thu 1/26/17**	**Wed 7/12/17**
Superstructure	**37 days**	**Tue 6/20/17**	**Wed 8/9/17**
Install Gym Equipment	**12 days**	**Wed 8/2/17**	**Thu 8/17/17**
Landscaping	1 wk	Thu 8/10/17	Wed 8/16/17
Stucco Painting	11 days	Mon 8/7/17	Mon 8/21/17
Project Completion	**0 days**	**Mon 8/21/17**	**Mon 8/21/17**

Figure 2: Baseline Schedule

Critical Path

The critical path includes the demolition of existing, construction of footings, erection of steel and exterior enclosure. The interior construction activities are also on the critical path, followed by the final commissioning and components related to landscaping. The critical activities include:

- demolition of existing
- footings
- excavations
- concrete pouring
- erection of steel
- exterior enclosure
- elevated slab
- roofing
- interiors
- commissioning
- landscaping

Site Logistics Plan

In this section, our team will discuss the process of delivering materials to the construction job site and the potential safety hazards of maneuvering large loads through a crowded campus. Our team will cover our final site logistics plan and how dust control and student safety during construction activities has been addressed. Finally, our team will explain the difficulties with using cranes at our site and our unique solution to this problem.

Material Delivery Path

Anyone familiar with our campus will know that the current Malley Fitness Center is located in one of the most congested areas on campus. It is surrounded on all four sides by the library, Campisi Hall, Sullivan Aquatic Center and a parking structure. List made getting materials to our project site very difficult. Our team went through several brainstorming ideas, which can be seen in Appendix 4. Ultimately our team felt the best solution was using the university's main entrance, Palm Drive, and exit through the Levy parking lot onto El Camino Real. This route will involve turning left from Palm Drive and driving behind the Bannan Engineering Building before turning left again before reaching the construction job site. On Appendix 4, this is the route highlighted in red. Our design team felt that this was the best option because it presented a one way in, one way out delivery path. As compared to the other options considered, which involved more direct paths through campus, which could endanger student safety, or involved doubling back along the same path, which could potentially create truck traffic during multiple deliveries. Ultimately, our design team felt that the selected path presented the best option because of the flow of traffic and lack of use of main university student traveling paths, which will decrease the chance of student injury.

Site Logistics Plan

Our team laid out our proposed site logistics plan as can be seen in Appendix 5. As can be noted from the appendices, our team shows locations for a site trailer, security fencing and the aforementioned material delivery path. Our team realized for this project that security and dust control would be huge factors due to the construction sites location on campus and the fact that students would be on campus during construction. To proactively prevent any issues, our design team would use eight foot high chain link fencing with dust control blankets around the outside of the fencing. This would help in preventing any dust from making its way off site and into students paths, which would be a huge inconvenience for the students as well as general dirty making its way off site would disrupt the overall campus cleanliness. Additionally, the soil on the site will be kept moist to ensure a minimal amount of dust. Furthermore, our team recognized the importance of security for this project. Because students will be on campus while construction activities are going on, all equipment, materials and tools would be locked up at the end of the day. In addition, coordination between the construction team and campus safety would prove to be imperative for those times when construction personnel is not on site, like the weekends or weeknights. Campus safeties general role would be the protection of the students, with general monitoring of the site, our team believes we can proactively prevent any student from making their way onto the site and injuring themselves.

Anyone familiar with Santa Clara University's campus would note that the Solar Decathlon house is located within our construction site; this can also be seen in Appendix 5. Before construction began, it would be coordinated with the university as to the best location to relocate the house. Our team has considered several potential solutions, including the Sobrato lawn as a potential destination.

Crane Locations

As our team has highlighted, the construction site for this project is located in one of the most congested areas on our campus. This made it extremely difficult to determine potential crane locations with enough radiuses to reach the middle of the building, where the heaviest loads are, without the boom hitting the building. Ultimately our design team came up with a unique solution, which was outlined in the schedule section of this report of constructing the building from the middle outwards. A schematic of this approach with the corresponding crane locations and radiuses can be seen in Appendix 6. As the building is built and the building height of 45 feet is approach the crane radiuses will dramatically decrease. This effectively limits the range of the cranes and limits, which portions of the buildings can be reached. Appendix 7 shows what happens to the crane radiuses as the 45 foot building height is approached. Our team realized that Appendix 7 does not show that all parts of the exterior of the building are covered, but by moving the crane locations, all exterior portions of the building will be covered.

Facility Comparison

Our team wanted to take the opportunity to present a facility comparison between the current, Malley Fitness Center, and our proposed design, both on a square footage basis and a cost basis. First, Table 5 below shows the square footage of each area in both facilities as well as all additional rooms.

Table 5: Square footage comparison of Malley Fitness Center and our design

	Current Facility	Our Design
Workout Space	7,192	21,842
Cardio Space	2,582	9,932
Office Space	2,496	8,023
Multipurpose Rooms	1	5
Basketball Courts	3	4
Additional Design Features		3 Badminton Courts Training Room

Additionally, our team wanted to present a cost comparison between our proposed design and the Malley facility built in 1999. As should be noted in Table 6, the cost of the building in 1999 has been converted to today's dollars, by assuming an average inflation rate of 3% per year for the 16 year period.

Table 6: Cost comparison of Malley Fitness Center and our design

	Current Facility	Our Design
Total Square Footage	45,000	113,602
Total Cost (1999)	$ 8,800,000	
Cost per SF (1999)	$ 195.56	
Total Cost (2015)	$ 14,121,417	$ 18,211,738
Cost per SF (2015)	$ 313.81	$ 160.31

As both Table 5 and 6 shows, our design provides increased space, at a limited cost to the school as compared to the originally built facility.

Conclusion

The proposed design would address one the largest issues facing Santa Clara University, a lack of an adequately sized fitness facility for our active and growing student body. We believe with our design, we have addressed many of the core issues facing the current facility and can prove a long term solution for the university and its students. Our 113,602 SF proposed design, provides increased workout and cardio spaces, additional multipurpose rooms and basketball courts, designated badminton courts and additional training and office space for student and university use. Our design team concluded that our proposed design addressed all of the issues facing the current Malley Facility and can become a hallmark building on a growing and active campus.

Works Cited

"Kermit Rudolf Fitness Center." *Gozags.com*. N.p., n.d. Web. 12 Oct. 2014.

"Recreation Leading the Stanford Experience." *Stanford Recreation*. Stanford University, n.d. Web.

"Santa Clara University." *Campus Recreation -Malley Center*. Santa Clara University, n.d. Web.

"Santa Clara University." -*Enrollment Plan*. Santa Clara University, n.d. Web. 12 Oct. 2014.

"Santa Clara University Bulletin and Student Handbook." (n.d.): n. pag. Santa Clara University, 1999.Web.

"Santa Clara University Bulletin and Student Handbook." (n.d.): n. pag. Santa Clara University, 2014.Web.

Appendix

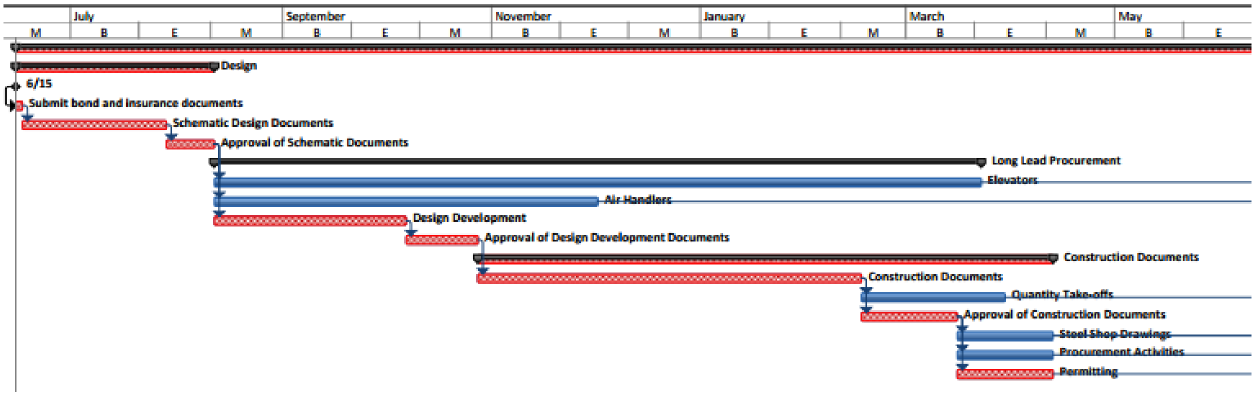
Appendix 1 – Complete Cost Estimate

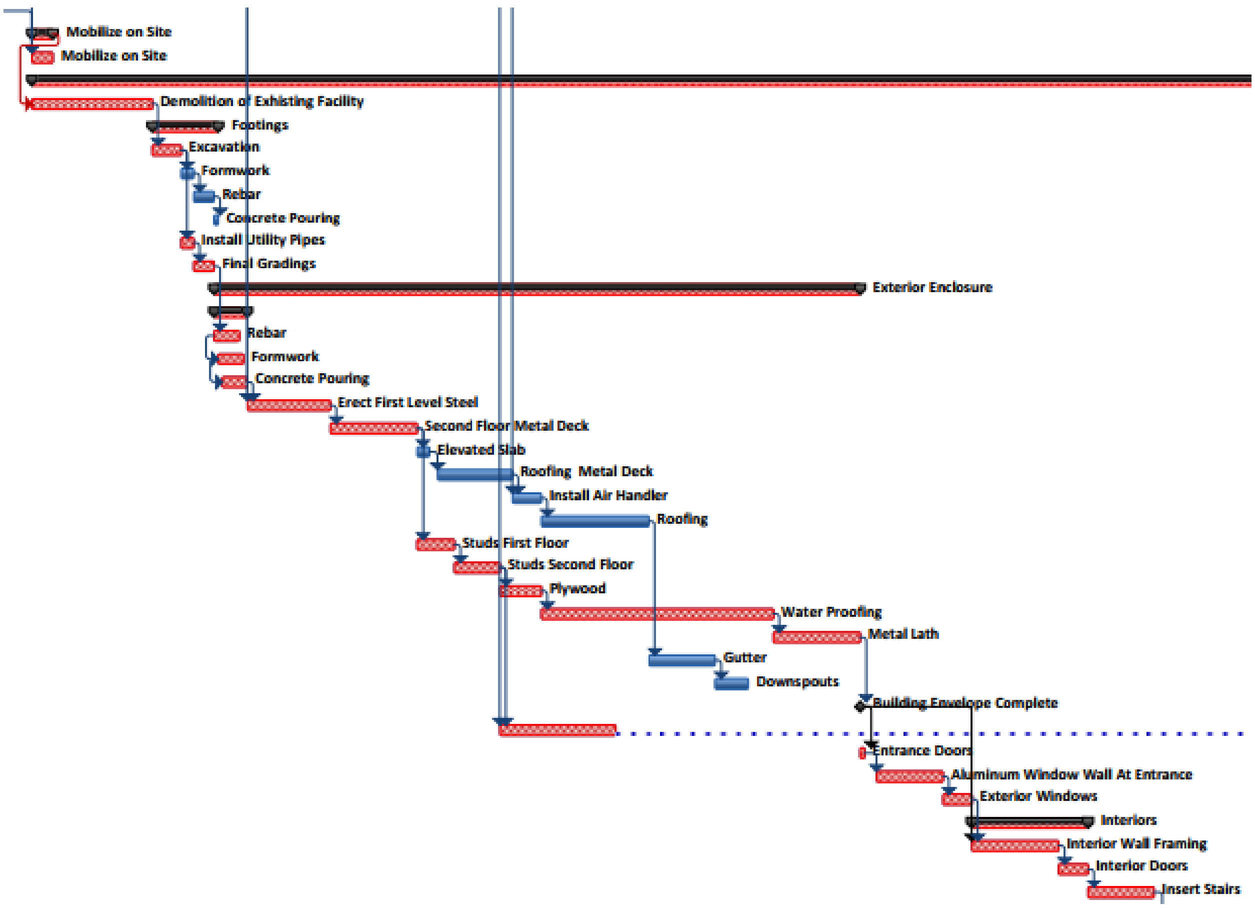
	UNIT	QUANTITY	$/UNIT	TOTAL COST
DEMOLITION	LS	1	$65,000.00	$65,000.00
SUBSTRUCTURE				
Slab on Grade - 4" reinforced with Vapor Barrier and Base	SF Slab	56,801	$5.58	$316,956.40
Standard Foundations - Strip and Spread Footings	SF Ground	56,801	$1.89	$107,306.18
Excavation	SF Ground	56,801	$0.87	$49,621.35
SHELL				
Roofing Coverings - TPO, Fully Adhered Poly-iso insulation	SF Roof	56,801	$6.12	$347,406.28
Roof and Second Floor Metal Deck	SF Roof	113,602	$2.54	$288,412.76
Exterior Windows	EA	40	$534.55	$21,381.84
Elevated Slab	SF	56,801	$4.46	$253,296.11
Reinforcement for Elevated Slab	CSF	56	$61.67	$3,460.29
Formwork for Elevated Slab	SF	56,108	$0.14	$7,768.15
Clay Roof Tiles	SQ	100	$986.67	$98,667.00
Entrace Doors	EA	2	$5,514.75	$11,029.50
Glazed Curtain Wall Around Cardio Area	SF	4,420	$87.72	$387,735.66
Aluminum Window Wall at Entrance	SF	1,560	$79.52	$124,043.40
Gutter	LF	1,403	$9.58	$13,438.21
Downspout	LF	1,050	$5.18	$5,440.53
Stucco Finish	SF	33,285	$1.09	$36,325.25
Stucco Waterproofing	SF	33,285	$3.89	$129,444.70
Stucco Metal Lath	SY	1,233	$5.53	$6,820.10
Exterior Metal Studs	SF	33,285	$5.71	$190,057.35
Exterior Plywood	SF	33,285	$1.36	$45,267.60
Structural Steel	LBS	716,741	$1.25	$898,614.03
Steel Erection	LBS	716,741	$0.80	$575,112.98
INTERIOR FINISHES				
Basketball/Badminton/Multipurpose Court Flooring	SF	48,593	$13.10	$636,762.67
ACT Ceiling Tile in Office and Restrooms	SF	13,544	$4.12	$55,828.37
Carpeting in Office and Hallways	SY	766	$33.85	$25,929.38
Ceramic Tile in Bathrooms and Training Room	SF	8,475	$14.20	$120,311.10
Weight lifting/ Cardio Flooring (Rubber Rolls)	SF	31,966	$2.46	$78,540.46
Linoleum Flooring for Lobby	SF	2,704	$5.46	$14,763.84
Interior Doors and Frames	EA	30	$820.80	$24,624.00
Painting	SF	69,000	$0.51	$35,024.40
Lockers	EA	20	$376.89	$7,537.86
Saunas and Heaters in Mens/Womens Restrooms	EA	2	$10,000.00	$20,000.00
Steam Baths in Mens/Womens Restrooms	EA	2	$2,975.00	$5,950.00
Drywall	SF	69,000	$2.05	$141,381.00
Metal Studs	SF	69,000	$5.71	$393,981.72
Workout Mirrors	SF	11,610	$21.26	$246,779.26
Stairs	Flight	4	$6,000.00	$24,000.00
Lobby Mirror Wall	SF	1,560	$8.88	$13,857.48
Elevator	EA	1	$8,100.00	$8,100.00
Plumbing Fixtures	EA	26	$5,001.72	$130,044.72
Acoustical Panels in Gym	LF	700	$73.18	$51,228.45
SERVICES				
HVAC	SF Floor	113,602	$12.72	$1,444,705.03
Fire Protection	SF Floor	113,602	$5.43	$616,855.45
Electrical	SF Floor	113,602	$17.40	$1,977,104.22
Domestic Water Distribution	SF Floor	113,602	$4.76	$540,252.49
OTHER SPECIALTIES				
500 KW Solar Panel System	LS	1	$852,500.00	$852,500.00
Gym Curtain Dividers	SF	8,460	$19.82	$167,719.29
Basketball Hoops	EA	8	$5,500.00	$44,000.00
Scoreboards	EA	4	$4,000.00	$16,000.00
Sound System	EA	10	$1,975.00	$19,750.00
Gym Matts	SF	2,000	$4.68	$9,352.00
Operable Walls in Office Area	SF	8,316	$34.22	$284,594.31
SUBTOTAL				$11,990,083.16

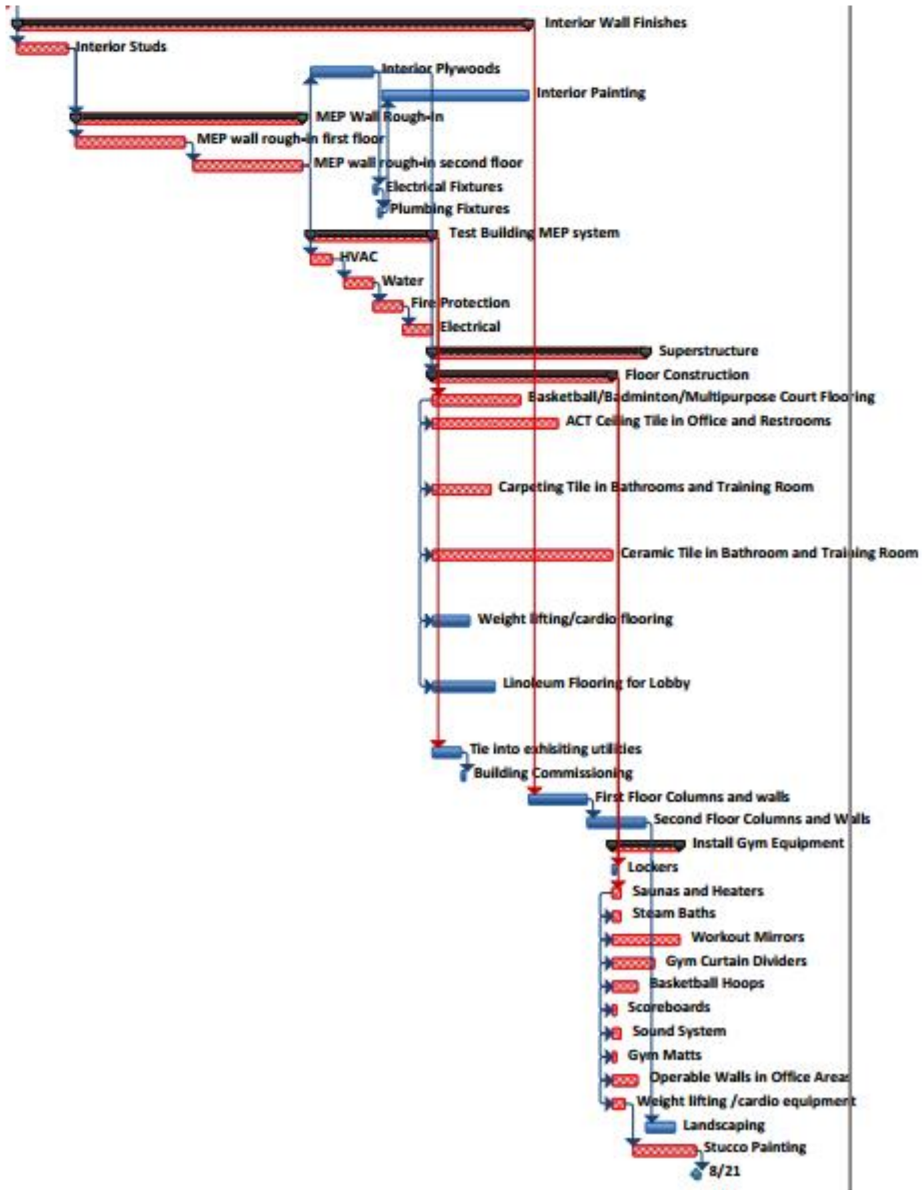
PERCENTAGE BASED COST

General Requirements	10%	$1,199,008.32
Building Commissioning	0.25%	$29,975.21
Preconstruction Services	6%	$719,404.99
General Insurance	0.64%	$76,736.53
Contractor Contingency	7%	$839,305.82
Permits and Licensing Fees	3%	$359,702.49
Design Fees	10%	$1,199,008.32
Overhead and Profit	15%	$1,798,512.47
TOTAL COST		$18,211,737.31

Appendix 2 – Gantt Chart of Proposed Schedule

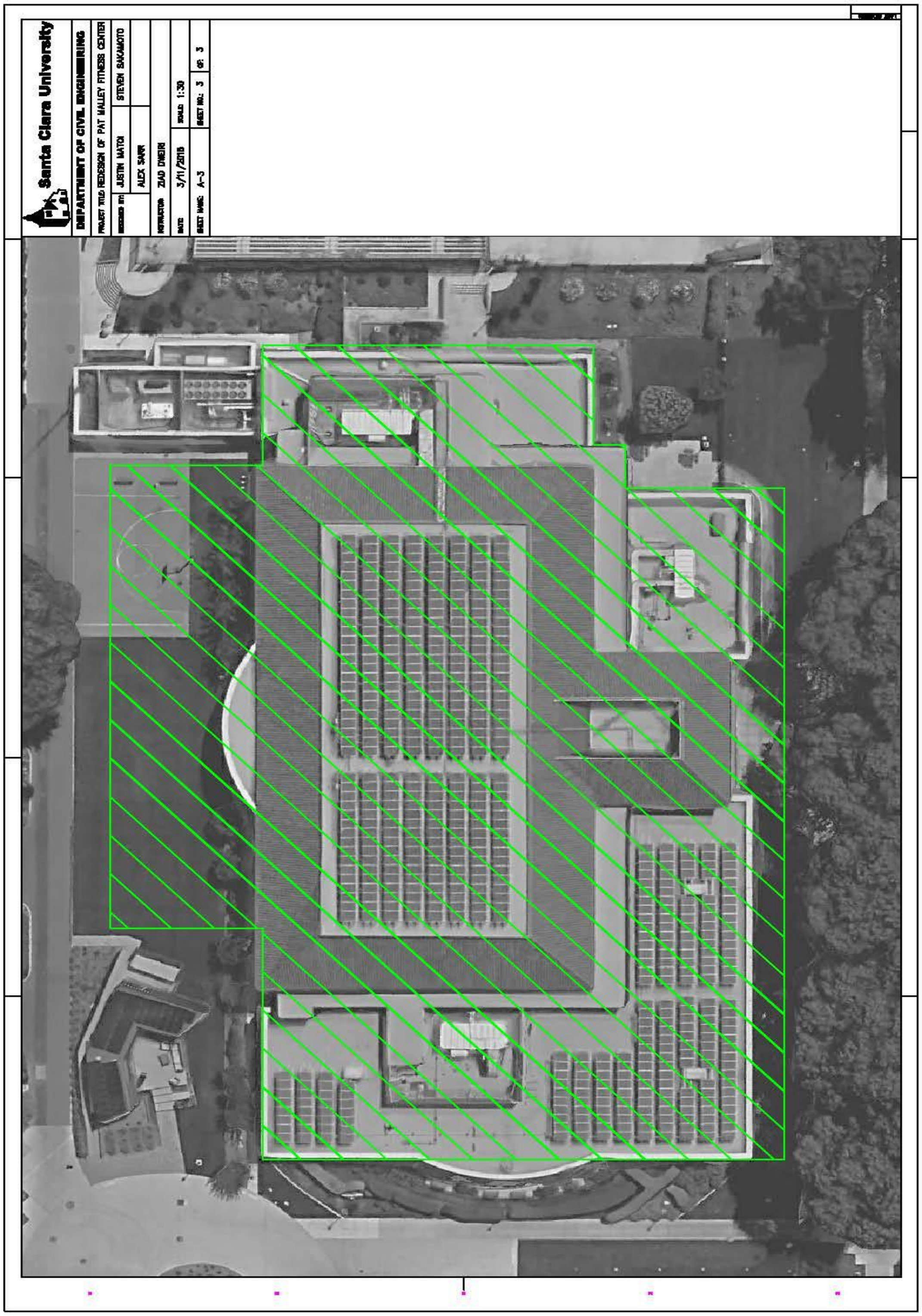




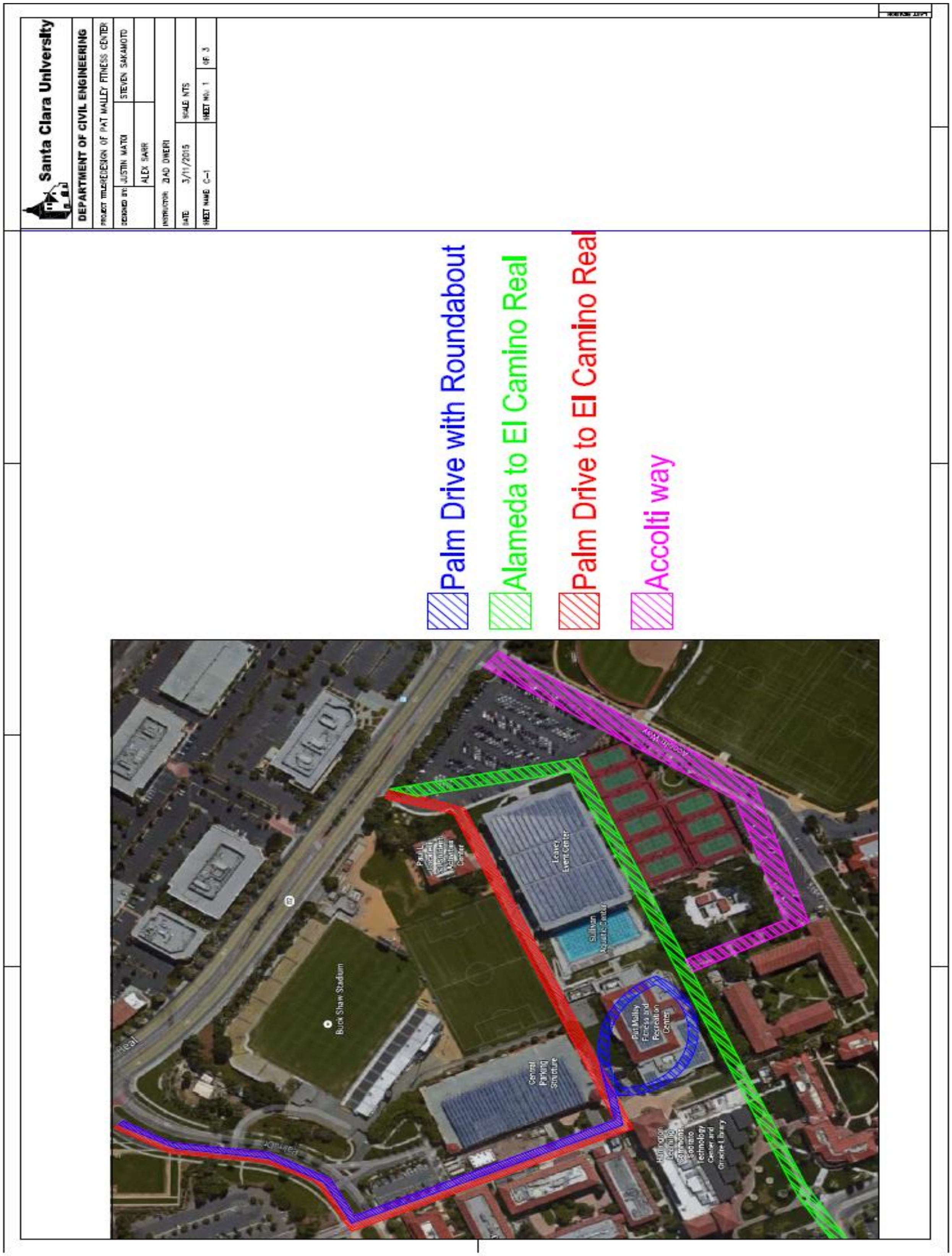


Interior Wall Finishes
Interior Studs
Interior Plywoods
Interior Painting
MEP Wall Rough-in
MEP wall rough-in first floor
MEP wall rough-in second floor
Electrical Fixtures
Plumbing Fixtures
Test Building MEP system
HVAC
Water
Fire Protection
Electrical
Superstructure
Floor Construction
Basketball/Badminton/Multipurpose Court Flooring
ACT Ceiling Tile in Office and Restrooms
Carpeting Tile in Bathrooms and Training Room
Ceramic Tile in Bathroom and Training Room
Weight lifting/cardio flooring
Linoleum Flooring for Lobby
Tie into exhisiting utilities
Building Commissioning
First Floor Columns and walls
Second Floor Columns and Walls
Install Gym Equipment
Lockers
Saunas and Heaters
Steam Baths
Workout Mirrors
Gym Curtain Dividers
Basketball Hoops
Scoreboards
Sound System
Gym Matts
Operable Walls in Office Areas
Weight lifting /cardio equipment
Landscaping
Stucco Painting
8/21

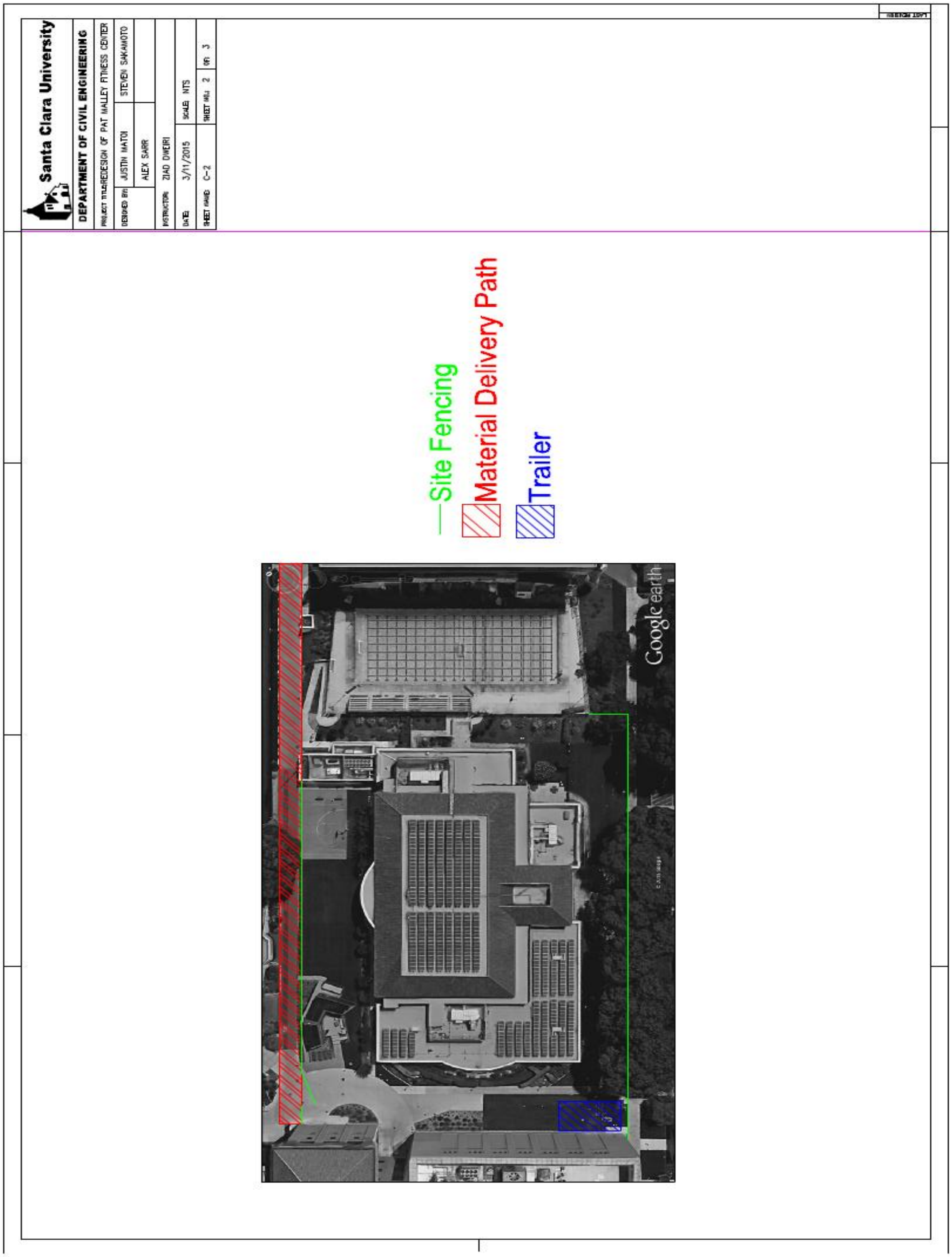
Appendix 3 – Building Overlay



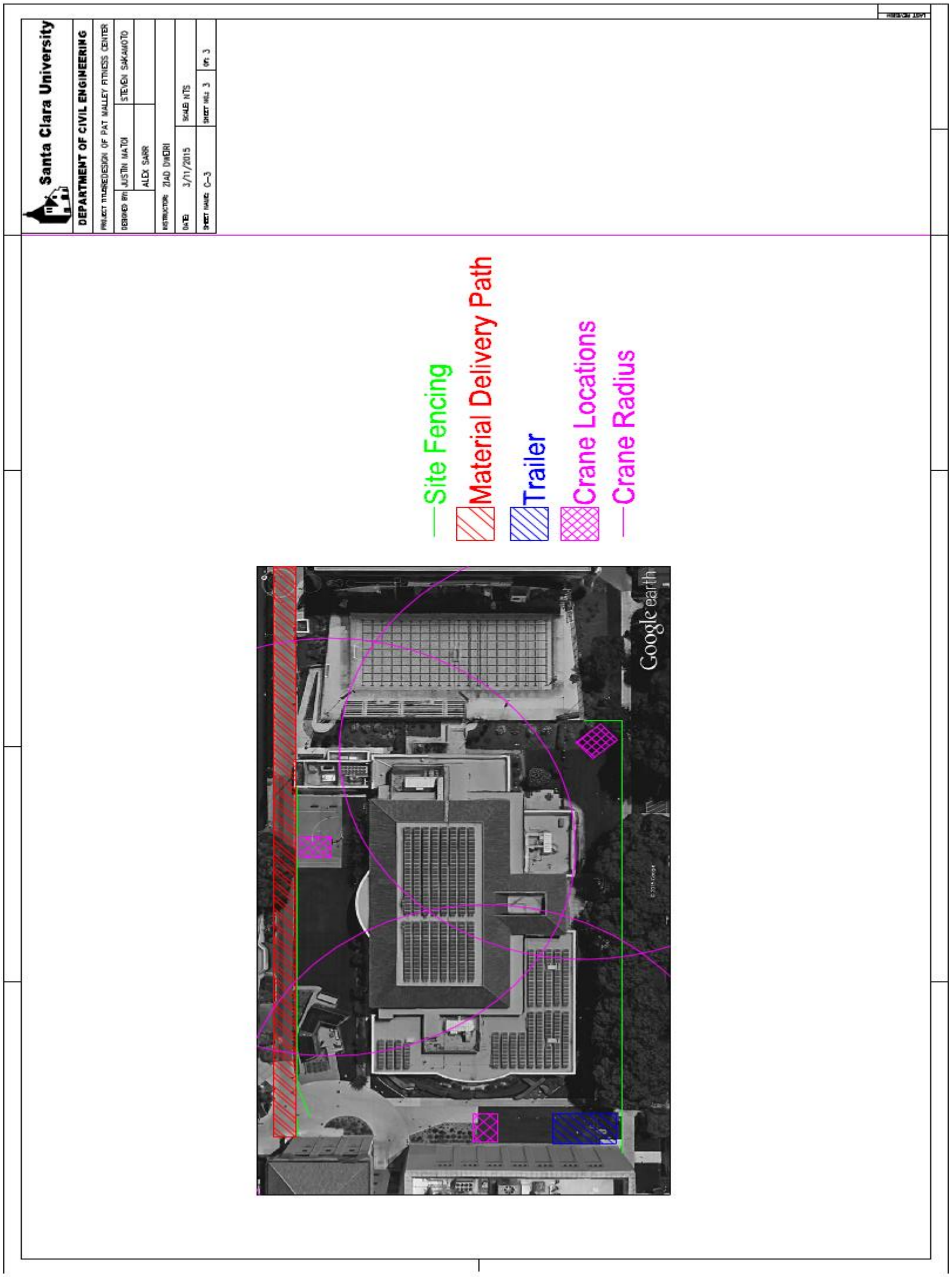
Appendix 4 – Material Delivery Path



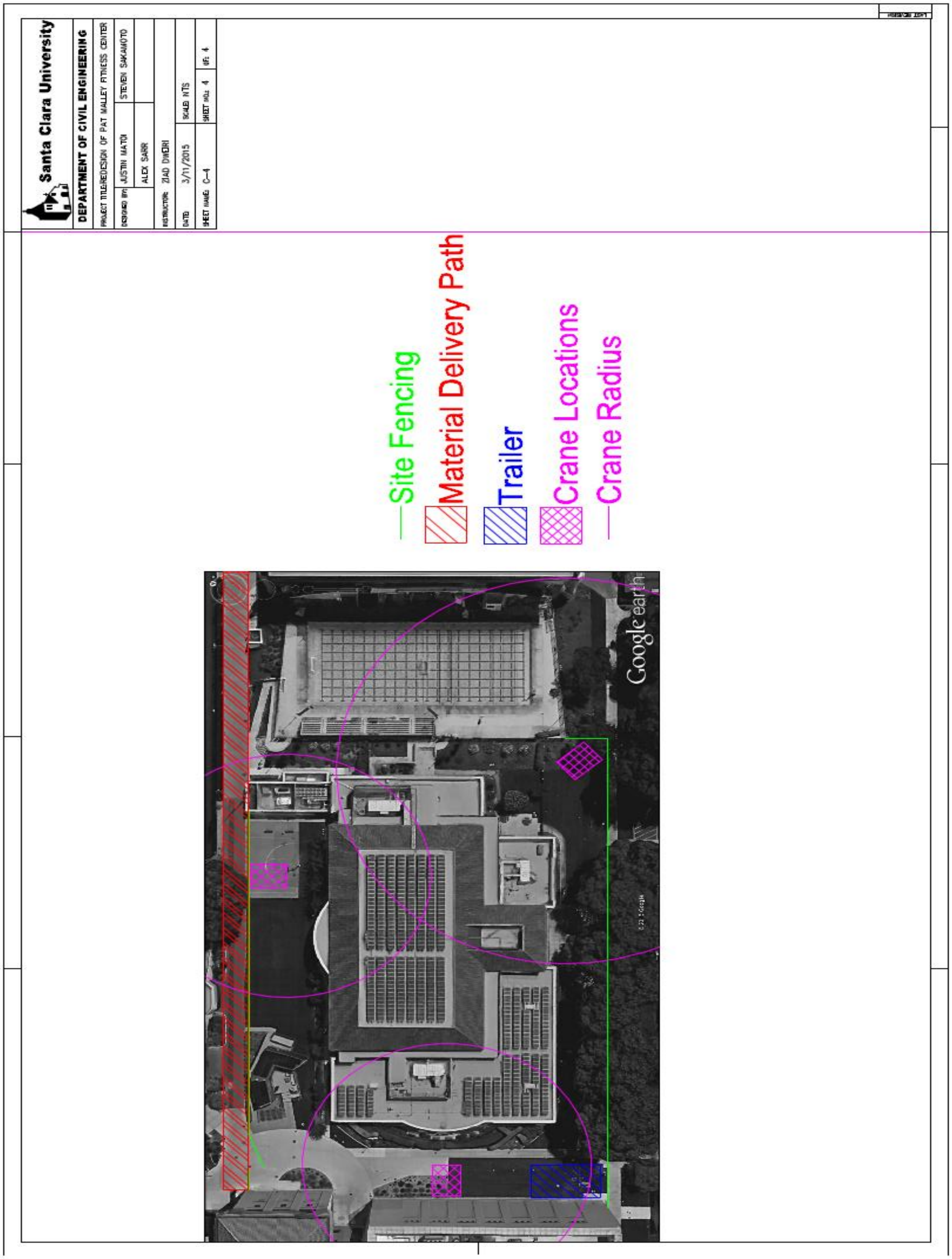
Appendix 5 – Site Logistics Plan



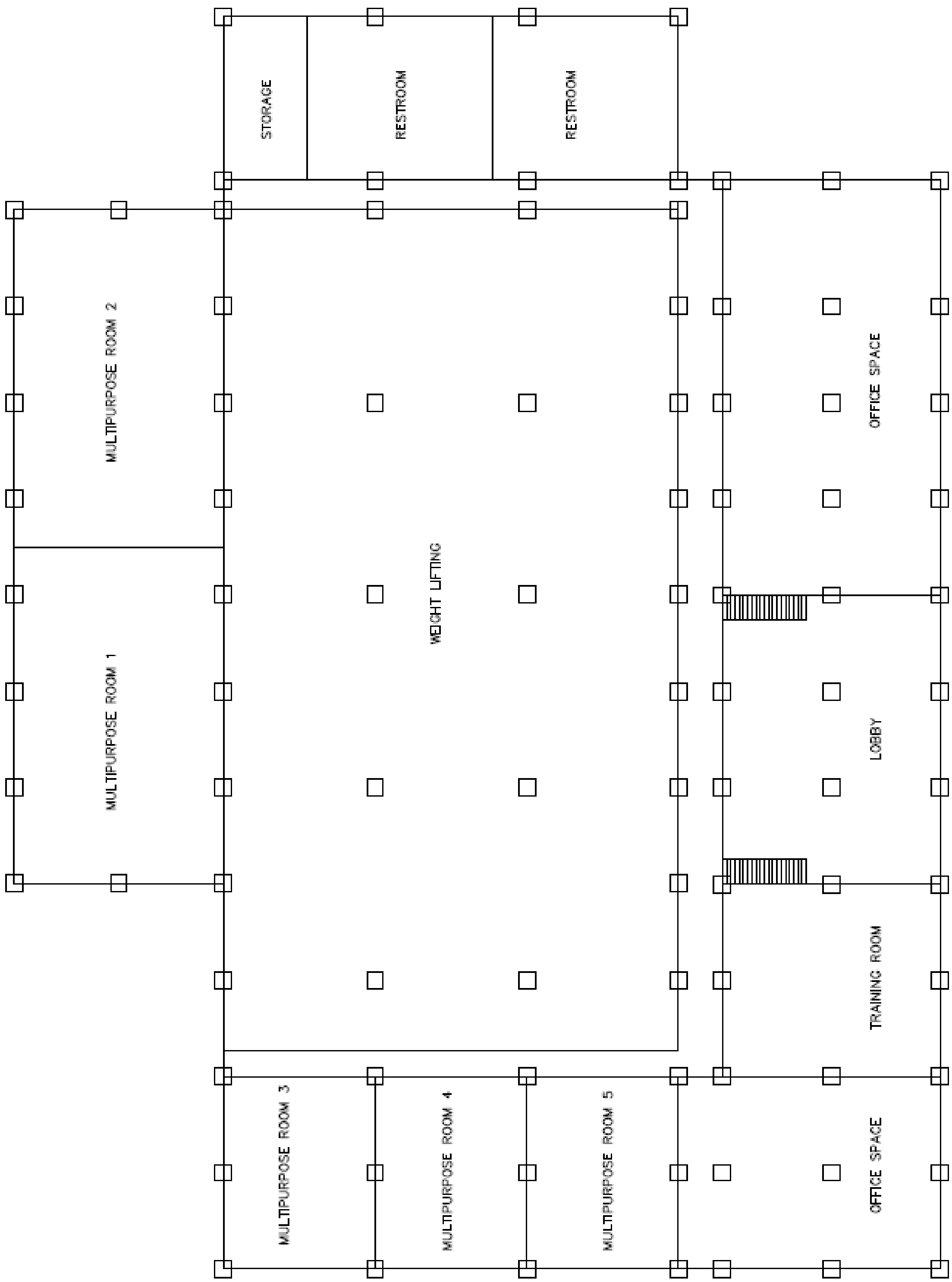
Appendix 6 – Crane Locations and Radiuses



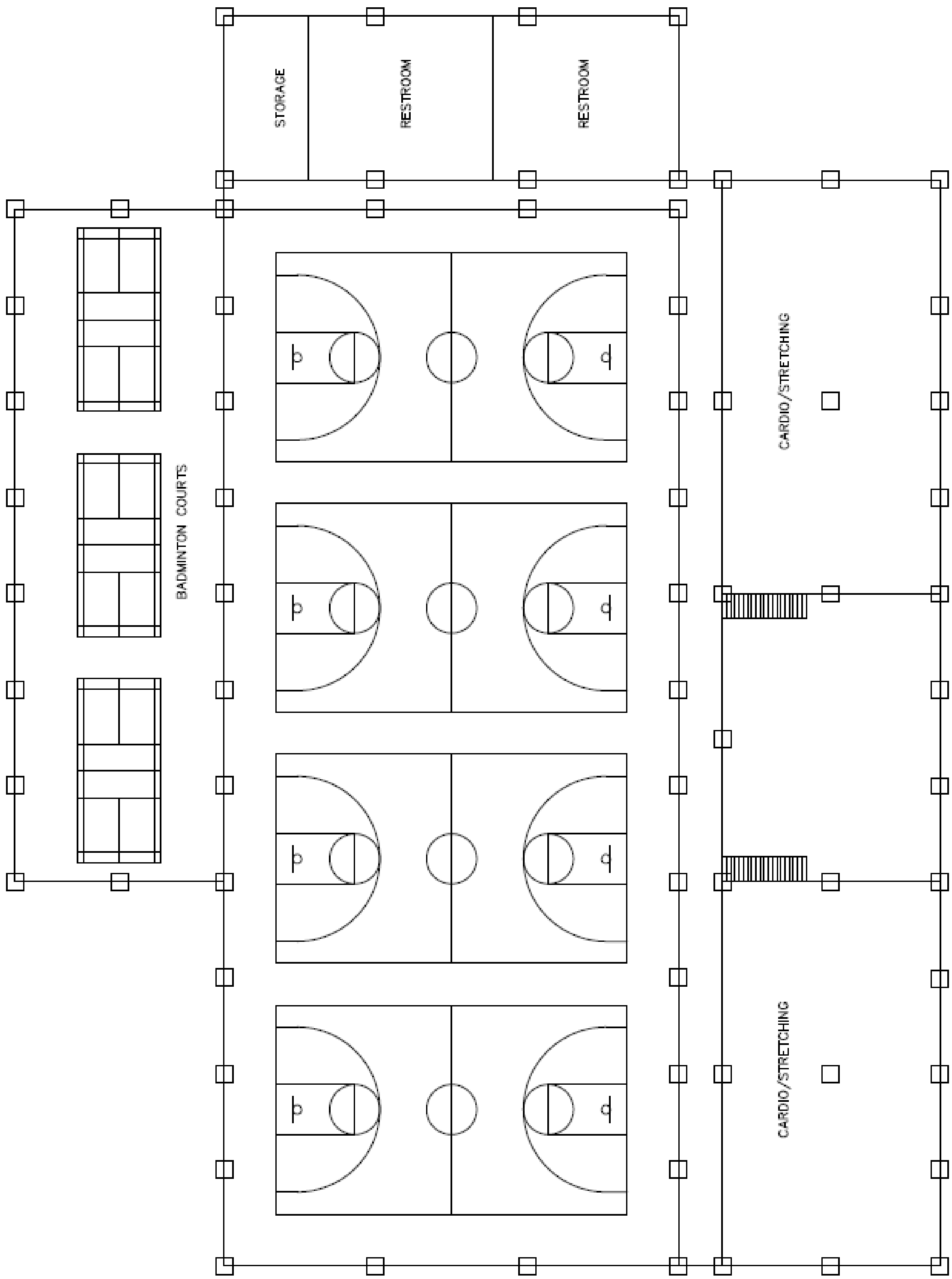
Appendix 7 – Crane Radiuses with 45 feet Governing



Appendix 8 – Column Location for First Floor



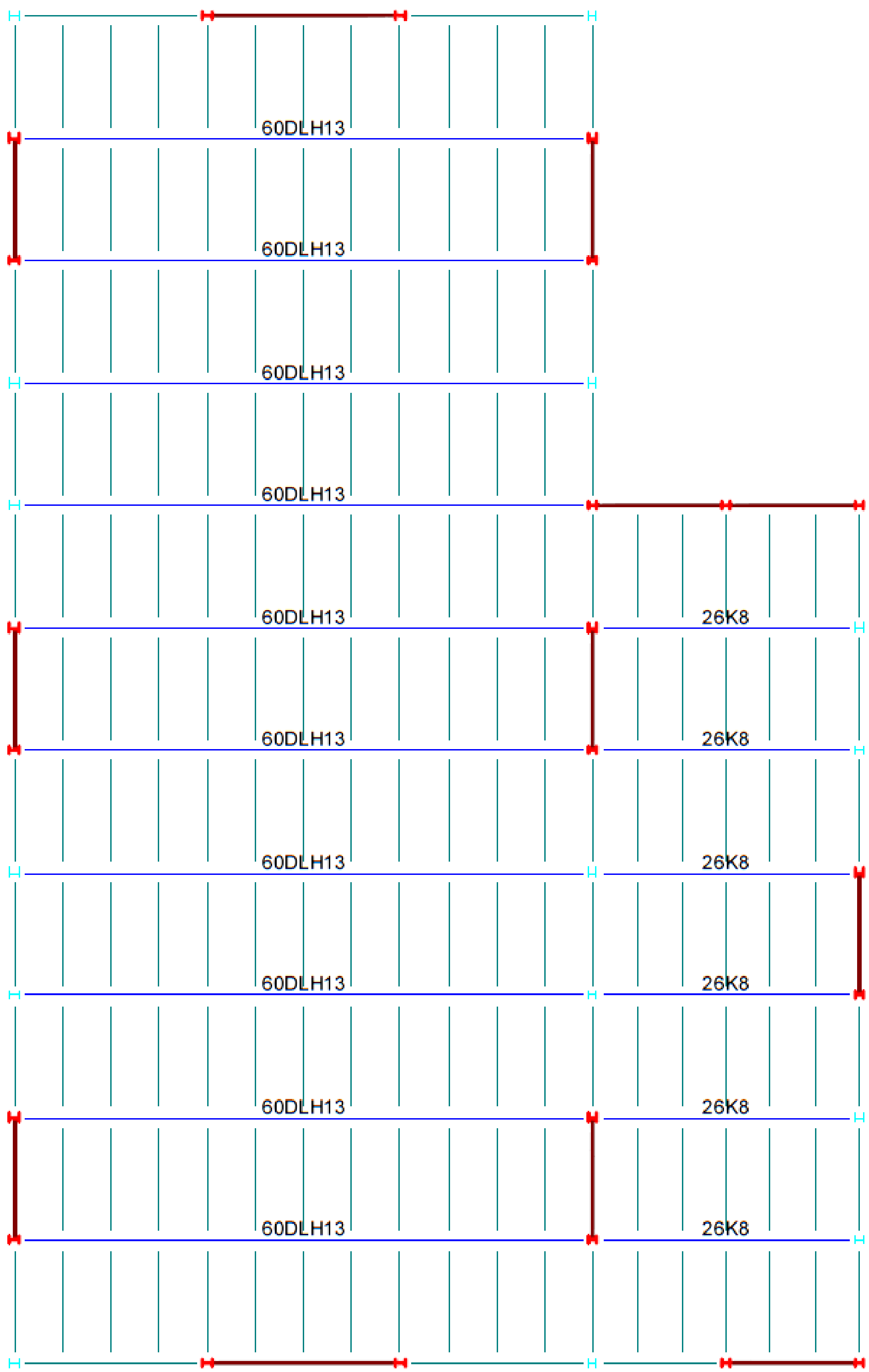
Appendix 9 – Column Location for Second Floor



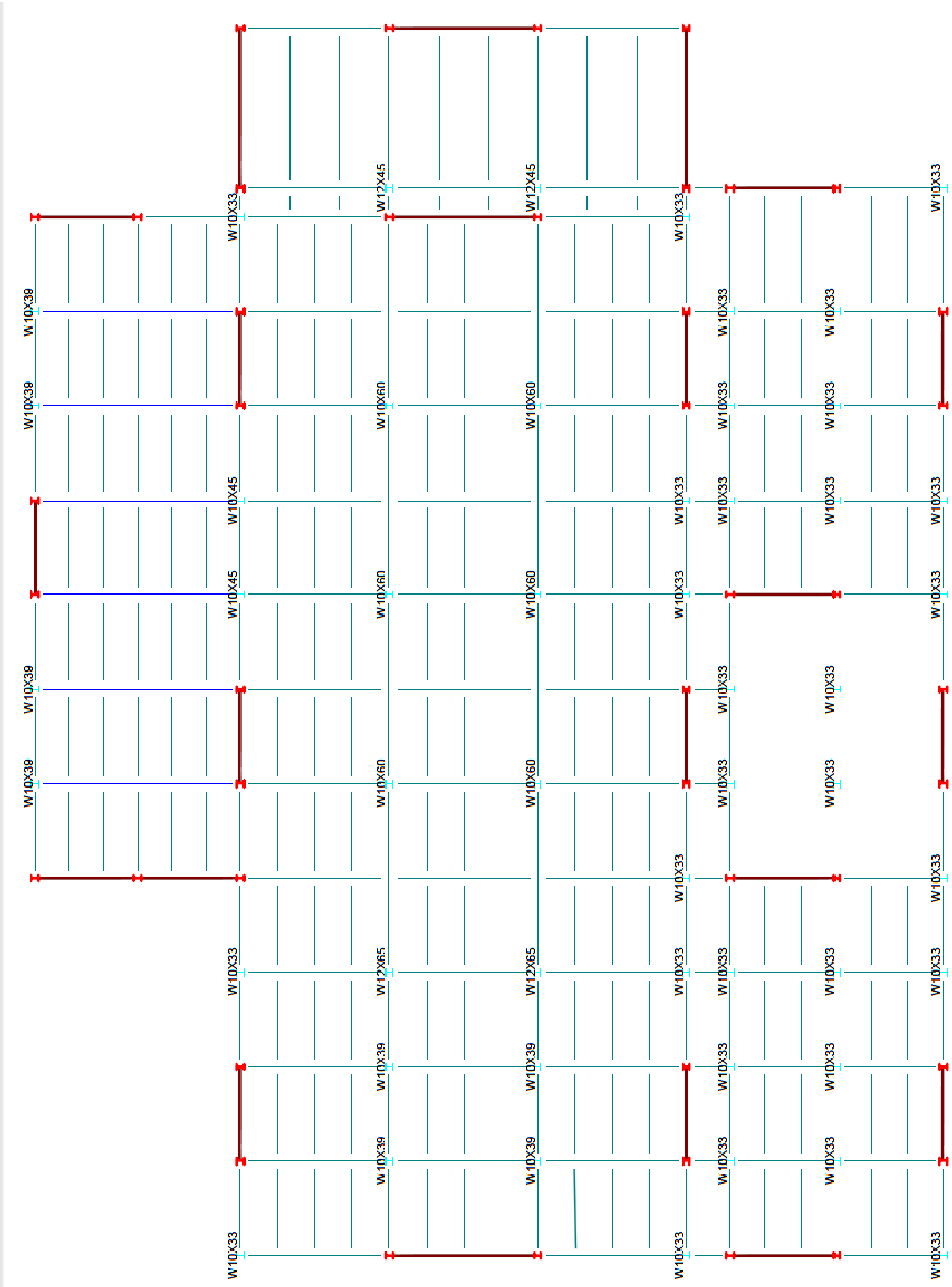
Appendix 10 – Second Floor Beam Sizes

Appendix 11 – Roofing Beam Sizes

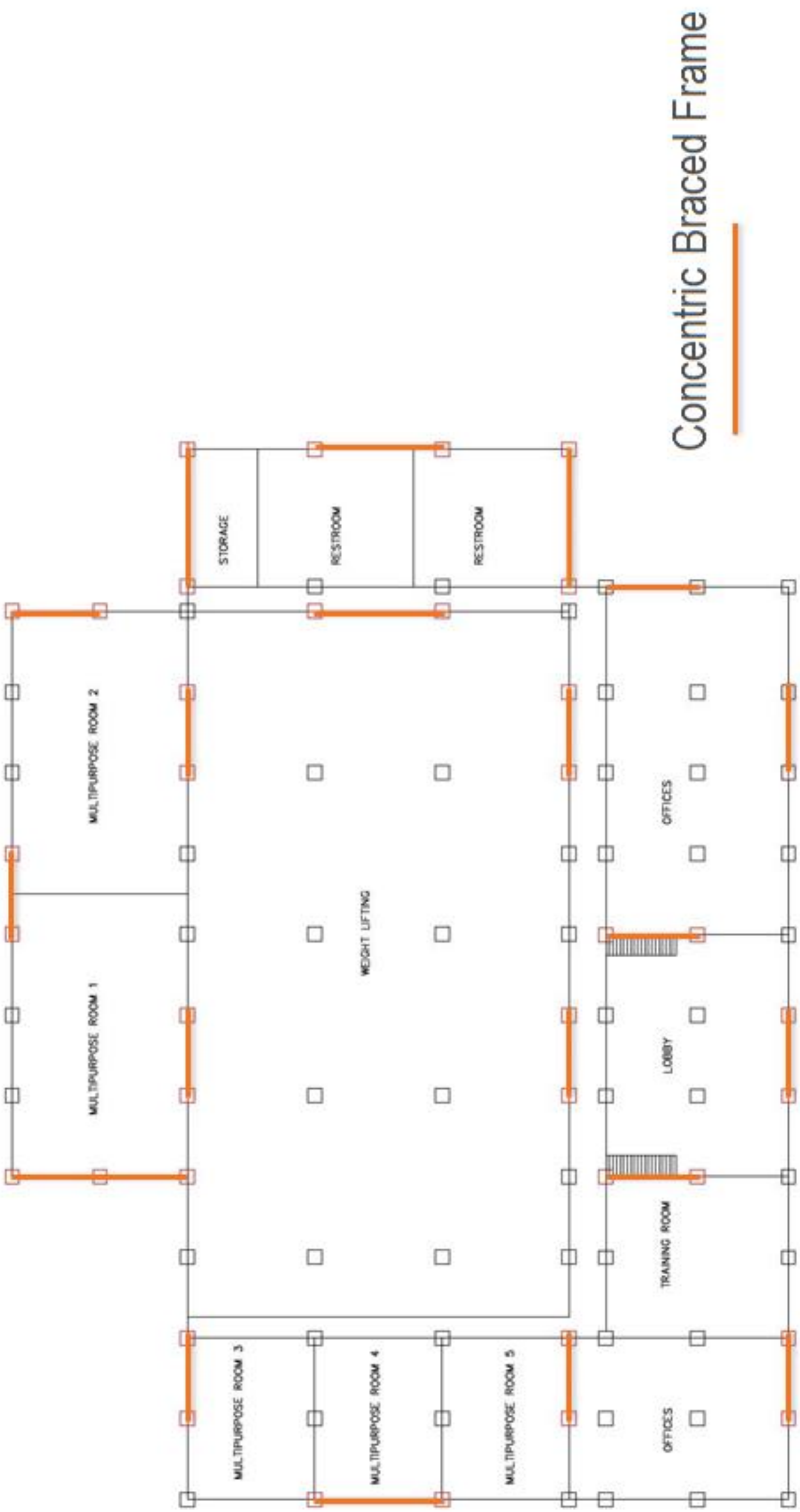
Appendix 12 – Steel Joist Sizes



Appendix 13 – Gravity Column Member Sizes

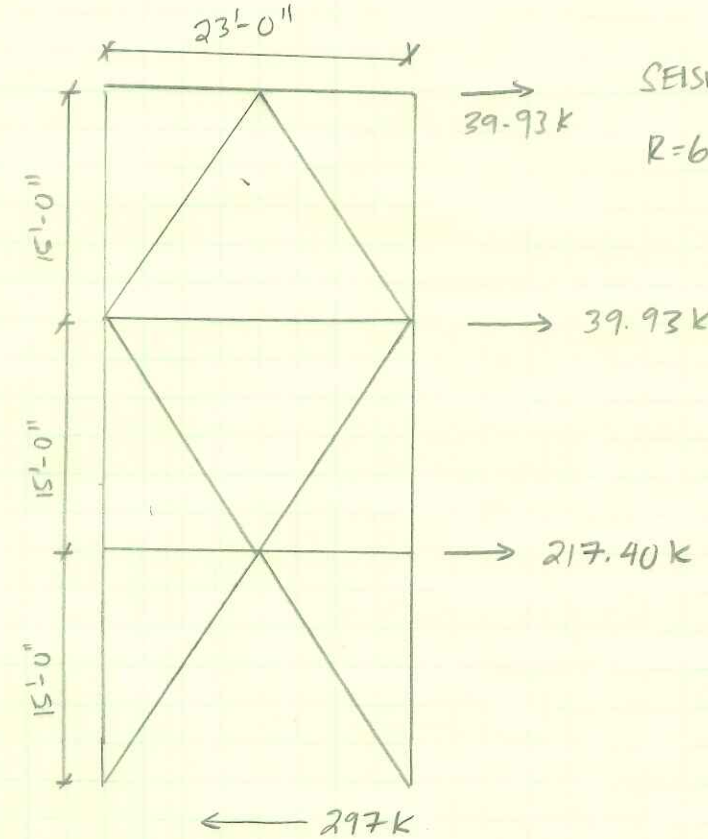


Appendix 14 – Lateral Bracing Location



Appendix 15 - Calculations

CONCENTRIC BRACED FRAMES



SEISMIC DATA:

$R=6 \quad \Omega_0=2 \quad \rho=1.3 \quad S_{DS}=1.0$

SCBF BRACE DESIGN

<u>DESIGN</u>: FIRST LEVEL BRACE

<u>GIVEN</u>: $P_D = 11.12$ KIPS $\quad P_L = 13.91$ KIPS $\quad P_E = 58.22$ KIPS
INTERSTORY DRIFT: 0.300 IN
USE ASTM A500 GR B SQUARE HSS

<u>MATERIAL PROP</u>: (AISC 360 TABLE 2-4)
$F_y = 42$ KSI $\quad F_u = 58$ KSI

<u>FACTORED LOADS</u>

MAX COMPRESSION

LOAD COMBO: $U = (1.2 + 0.2 S_{DS}) D + \rho Q_E + 0.5L$

$= (1.2+0.2(1))11.12 + 1.3(58.22) + 0.5(13.91)$

$= 98.0$ K COMP

MAX TENSION

LOAD COMBO: $U = (0.9 - 0.2 S_{DS}) D - \rho Q_E$

$= [0.9-0.2(1)]11.12 - 1.3(58.22)$

$= -68.0$ K TENSION

UNBRACED LENGTH

$$L = \sqrt{15' + 11.5'} = 18.90' = 226.81''$$

PΔ EFFECTS

AISC 360 Eq A-8-2 $\quad P_U = P_{grav} + B_2 P_{EQ}$

WHERE $B_2 = \dfrac{1}{1 - \dfrac{\alpha P_{story}}{P_{estory}}}$, $\alpha = 1.0$ FOR LRFD

$P_{STORY} = 703.41$ KIPS

H_{STORY} SHEAR: 297×2 FRAMES $= 594$ KIPS

$R_M = 1.0$ FOR BRACED FRAMES

$$P_{estory} = R_M \frac{HL}{\Delta_H} = 1.0 \left(\frac{594 \cdot 15' \times \frac{12''}{1}}{0.30} \right) = 356{,}400 \text{ K}$$

$$B_2 = \frac{1}{1 - \frac{1.0(594)}{356{,}400}} = 1.001 \leftarrow$$ NO CHANGES TO P_U COMP & TENSION

BRACE: WIDTH THICKNESS

TRY REC HSS $6 \times 6 \times 5/16$

$$\lambda_{hd} = 0.55 \sqrt{\frac{29000}{42}} = 17.6$$

$b/t = 14.2 < \lambda_{hd}$ ✓ SECTION IS SEISMICALLY COMPACT

BRACE COMPRESSION CAPACITY
AISC 360 TABLE 4-4

$\left.\begin{array}{l} \text{HSS } 6 \times 6 \times 5/16 \\ KL = 18.9 \end{array}\right\}$ $\phi P_n = 138$ KIPS $> P_u = 98$ KIPS ✓

BRACE TENSION CAPACITY
AISC 360 TABLE C-5

HSS $6 \times 6 \times 5/16$ $\quad \phi P_n = 266$ KIPS $> P_u = 68$ KIPS ✓

$\boxed{\text{SCBF BRACE 1st LEVEL} \quad \text{USE HSS } 6 \times 6 \times 5/16}$

DESIGN: SECOND LEVEL BRACE

GIVEN: $P_D = 5.08$ KIPS $P_L = 6.05$ KIPS $P_E = 11.19$ KIPS
INTERSTORY DRIFT: 0.4047
USE ASTM A500 GR B SQUARE HSS

FACTORED LOADS
MAX COMPRESSION

LOAD COMBO = $U = (1.2 + 0.2(1))6.05 + 1.3(11.19) + 0.5(5.08)$
$= 25.557$ KIPS

MAX TENSION

LOAD COMBO: $U = (0.9 - 0.2(1))5.08 - 1.3(11.19)$
$= -11.00$ KIPS

UNBRACED LENGTH

$L = \sqrt{15' + 11.5'} = 18.90'$

PΔ EFFECTS: ARE NEGLIGIBLE

BRACE WIDTH THICKNESS
TRY SQU HSS 5X5X1/4

$\lambda_{hd} = 0.55\sqrt{\frac{29000}{42}} = 14.5$

b/t : 18.5 ✓ SECTION IS SEISMICALLY COMPACT

BRACE COMPRESSION CAPACITY
AISC 360 TABLE 4-4

$\left.\begin{array}{l}\text{HSS } 5\times5\times1/4 \\ KL = 18.9\end{array}\right\}$ $\phi P_n = 69.6$ KIPS $> P_u = 25.6$ KIPS ✓

BRACE TENSION CAPACITY
AISC 360 TABLE 5-5

HSS 5X5X1/4 } $\phi P_n = 178$ KIPS $> P_u = 11.00$ KIPS ✓

SCBF BRACE 2ND LEVEL LOWER ROOF USE HSS 5X5X1/4

DESIGN: 3RD FLOOR (UPPER ROOF) BRACE

GIVEN: $P_D = 1.29k$ $P_L = 1.60k$ $P_E = 10.84k$
USE ASTM A500 GR B SQUARE HSS

FACTORED LOADS:
MAX COMP

LOAD COMBO = $U = (1.2 + 0.2 S_{DS}) D + \rho Q_E + 0.5L$
$= (1.2 + 0.2(1.0)) 1.29 + 1.3(10.84) + 0.5(1.60)$
$= 16.70$ KIPS

MAX TENSION

LOAD COMBO: $U = (0.9 - 0.2 S_{DS}) D - \rho Q_E$
$= (0.9 - 0.2(1)) 1.29 - 1.3(10.84)$
$= -13.19$ KIPS

UNBRACED LENGTH:

$L = \sqrt{15' + 11.5'} = 18.90'$

PΔ EFFECTS ARE NEGLIGIBLE

BRACE WIDTH THICKNESS
TRY HSS 4x4x3/16
$\lambda_{hd} = 0.55\sqrt{\frac{29000}{42}} = 14.2$
$b/t = 20$ ✓ SECTION IS SEISMICALLY COMPACT

BRACE COMPRESSION CAPACITY
AISC 360 TABLE 4-4

$\left.\begin{matrix}\text{HSS } 4\times4\times3/16 \\ KL = 18.9\end{matrix}\right\} \phi P_n = 26.9 \text{ KIPS} > P_u = 16.70 \text{ KIPS}$ ✓

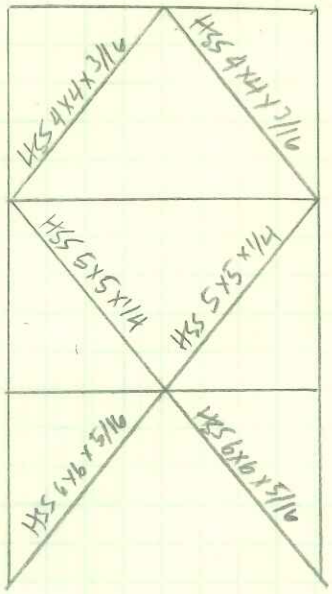
BRACE TENSION CAPACITY
AISC 360 TABLE 5-5

HSS 4x4x3/16 $\phi P_n = 107$ KIPS $> P_u = 13.19$ KIPS ✓

$\boxed{\text{SCBF BRACE 3RD LEVEL UPPER ROOF USE } 4\times4\times3/16}$

SCBF ANALYSIS

DETERMINE: THE EXPECTED STRENGTHS OF THE BRACES IN TENSION & COMPRESSION



A500 GRADE B:

$F_y = 46\text{ KSI}$ $F_u = 58\text{ KSI}$ $R_y = 1.4$ (AISC 341 TABLE A3.1)

BRACE PROP	AREA	r
6x6x5/16	$6.43 in^2$	2.30 in
5x5x1/4	$4.30 in^2$	1.92 in
4x4x3/16	$2.58 in^2$	1.54 in

- ACTUAL LENGTH BETWEEN CONNECTIONS = 14'

EXPECTED TENSION

AISC 341 F2.3 $P_{tension} = R_y F_y A_g = 1.4(46) A_g$

LEVEL	BRACE	TENSION
3	HSS 4x4x7/16	166 KIPS
2	HSS 5x5x1/4	277 KIPS
1	HSS 6x6x5/16	414 KIPS

EXPECTED COMPRESSION (AISC 341 F2.3)

HSS 6x6x5/16

$$\frac{KL}{r} = \frac{(1.0)(168)}{2.30} = 73.0$$

$$4.71\sqrt{\frac{E}{R_y F_y}} = 4.71\sqrt{\frac{29000}{1.4(46)}} = 99.94 > 73$$

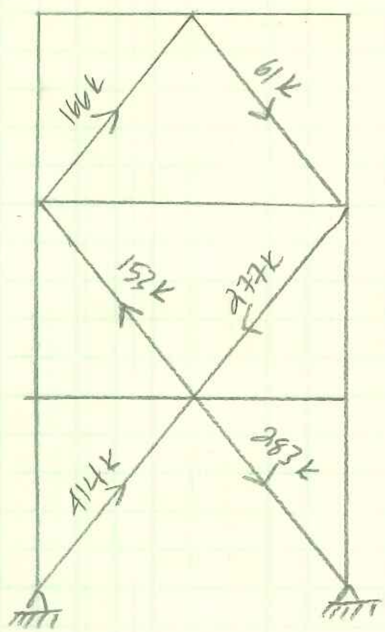
$$\therefore F_e = \frac{\pi^2(29000)}{(73.0)^2} = 53.71\text{ KSI}$$

$$F_{cr} = \left[0.658^{\frac{1.4(46)}{57.71}}\right]1.4(46) = 38.63$$

$$P_{comp} = 1.14(38.63\text{ KSI})(6.43\text{ in}^2) = 283\text{ KIPS}$$

SUMMARY OF COMPRESSION

LEVEL	BRACE	EXPECTED Pn	POST BUCKLING (0.3 Pn)
3	HSS 4x4x 3/16	61 k	18 k
2	HSS 5x5x 1/4	153 k	46 k
1	HSS 6x6x 5/16	283 k	85 k



TENSION + BUCKLING

SCBF COLUMN DESIGN

DESIGN: COLUMN C-1

GIVEN: A992 STEEL, WIDE FLANGE
$P_D = 96$ K $P_L = 91$ K $P_S = 12$ K $P_{QE} = 202$ kips

FORCE FROM BRACE:

BEAM SHEAR AT LEVEL 1

$$V = \frac{(277 + 283 - 414 - 153)\sin(52.52°)}{2} = 5.55\,K$$

BEAM SHEAR AT LEVEL 2

$$V = \frac{(61 + 277 - 153 - 166)\sin(52.52°)}{2} = 15.0\,K$$

COMPRESSION ABOVE BASE

$P_{EM} = (414 + 153 + 166)\sin 52.52 + (5.55 + 15.0)$
$P_{EM} = 572.23\,K$

TENSION ABOVE BASE

$P_{EM} = (-61 - 277 - 283)\sin(52.52) + (5.55 - 15.0)$
$= -502.25\,K$

A) COLUMN FORCE DUE TO EXPECTED BRACE STRENGTH

COMP:

$P_U = (1.2 + 0.2\,S_{DS})P_D + P_{EM} + 0.5\,P_L + 0.2\,P_S$
$= (1.2 + 0.2(1.0))\,96 + 572 + 0.5(91) + 0.2(12)$
$= 754\,K$

TENSION

$P_U = (0.9 - 0.2\,S_{DS})P_D - P_{EM}$
$= 0.9 - 0.2(1.0)\,96 - 502.25$
$= -435.05\,K$

B) FORCE FROM ELASTIC ANALYSIS

$P_{QE} = 202$ KIPS $\Omega_o = 2$

COMP

$P_U = (1.2 + 0.2(1))96 + 2(202) + 0.5(91) + 0.2(12)$

$= 586$ KIPS ← GOVERNS

TENSION

$P_U = (0.9 - 0.2(1))96 - 2(202)$

$= -336.8$ KIPS ← GOVERNS

PΔ EFFECTS ARE NEGLIGIBLE FROM BRACE CALCS

SELECT SIZES

COMP

AISC 360 TABLE 4-1 SMALLEST W10 WITH

KL = 15 $\phi P_n > 586$ = W12X65 ✓OK

TENSION

AISC 360 TABLE 5-1 W12X65 ϕP_n = 860 k ✓OK

$\boxed{\text{W12X65 FOR COLUMNS}}$

SCBF BEAM DESIGN

CHECK: BEAM FRAME 2 1st LEVEL

GIVEN: W12x48, A992

NON-COMP BUT SLAB PROVIDES BRACING ($L_b = 0$)

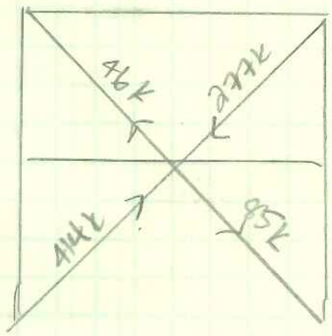
SHEARS: $V_D = 4.80$ KIPS $V_L = 6.25k$

$M_D = 11.04$ k-ft $M_L = 14.35$ k-ft

LOAD CASES

- CHECK BEAM FOR UNBALANCED FORCES DUE TO BRACE
- POST BUCKLING (GOVERNS)

UNBALANCED LOADS



$P_y = 414 + 46 - 277 - 85 \sin(52)$

$= 77k$

$V_{EN} = \frac{77k}{2} = 63k$

$M_{Eh} = \frac{63 \cdot (23)}{4} = 362.25$ k-ft

AXIAL FORCE IN BEAM

$P_x = \cos(52)\left[\frac{1}{2}\left[(414 + 85) - (46 + 277)\right]\right] = 54$ kips

FACTORED LOADS

$P_u = P_x = 54$ KIPS

$V_u = (1.2 + 0.2(1.0))(4.80) + 63k + 0.5(6.25)$

$= 72.873$ kips

$M_u = 1.4(11.04) + 362 + 0.5(14.35)$

$= 384$ kips-ft

MOMENT SHEAR CAPACITY

W21x48 $\phi M_p = 398 > M_u$ ✓

AISC 360 TABLE 3-2 $\phi V_n = 216 > V_u$ ✓

AXIAL CAPACITY

$L_y = 11.5$ (FLEX-TORSIONAL BUCKLING)
$\phi P_n = 316$ kips $> P_u$ ✓ok

COMBINED LOADING

$$\frac{54}{316} = 0.17 < 0.2 \quad \text{Eq H1-1b}$$

$$\frac{P_u}{2\phi P_n} + \frac{M_u}{\phi M_n} = \frac{54}{2(316)} + \frac{384\text{ k-ft}}{398\text{ k-ft}} = 1.05 > 1.0 \text{ X (NG)}$$

TRY W18X55

$\phi P_n = 571$ kips $> P_u$
$\phi M_n = 420$ kip-ft (AISC 360 TABLE 3-2)

$$\frac{54}{2(571)} + \frac{384}{420} = 0.961 < 1.0 \text{ ✓ok}$$

USE W18X55 FOR 1st FLOOR BEAM